C.E.S.A.R – Educational Unit of Recife Center for Advanced Studies and Systems

Rodolfo Ferreira Wagner

Modeling The Tipping Point of a Innovation Process using Cellular Automata

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Advisor: Professor Jones Oliveira de Albuquerque

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To my father, **Luiz** and my mother, **Úrsula**.

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The development of this work was possible only with the presence and support of very import people in my life.

First of all, I would like to thank all my family, who always give me all the necessary support and believed in my future.

To my father, Luiz Wagner Junior, who bet in my studies and contribute a lot in my professional and academic life and to my mother, Úrsula Ferreira Bezerra, that was always by my side during all this time.

To my two warriors' grandmothers, Nair and Zuleide, which are two examples of victory and perseverance.

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Finally, thanks to God, for giving me the necessary strength to continue in the most difficult times.

Thanks!

ABSTRACT

In the current economic scenario, innovation has been a key factor for companies become competitive and stand out in the market in which they operate. Thus, innovation has become the key for the economic development. Not long time ago, we discussed the role of the government and industry in the innovation process. Today, the innovation topic has transcended economic, social and governmental bounds. As the knowledge is the main factor that drives the innovative behavior, is not surprising that it has been the main actor in evidence in the society which we live nowadays. In this context, in addition to the industry and government, today we discuss the role of the universities as the main source of knowledge and technology transfer in the process of economic development. Thus, with the entrance of the university in the innovative sphere, it is formed an axis composed of three helices, industry-government-university that interact with each other, generating new and complex relationships, placing innovation into an evolutionary context. We named this concept Triple Helix. Our work provides a 3D simulator, based on cellular automata, with the capacity of generating scenarios, resulting from interactions between industry-government-university. Such scenarios will show us, whether in some regions of Pernambuco's state, is propitious the birth of innovative projects that came from a Triple Helix Model.

Keywords: Triple Helix. Innovation. University. Knowledge. Simulator. Cellular Automata.

Resumo

No cenário econômico atual, a inovação é um fator fundamental para as empresas se tornarem competitivas e se destacarem no mercado em que atuam. A inovação se tornou assim, a chave para o desenvolvimento da economia. Há muitos anos atrás se discutia o papel do governo e da indústria na esfera inovadora. Hoje, o tema inovação está à frente de barreiras econômicas, sociais e governamentais. Como o conhecimento é o principal fator que impulsiona o comportamento inovador, não é surpresa que ele seja o principal ator em evidência na sociedade que vivemos hoje. Neste contexto, além da indústria e do governo, atualmente discute-se o papel das universidades como principal fonte de conhecimento e transferência de tecnologia no processo de desenvolvimento econômico. Assim, com a entrada da universidade na esfera inovadora forma-se um eixo composto por três hélices, indústria- governo- universidade que interagem entre si gerando novas e complexas relações colocando a inovação em um contexto evolutivo. A este conceito dá-se o nome de Hélice Tríplice. Nosso trabalho oferece um simulador em 3D, baseado em autômatos celulares, capaz de gerar cenários resultantes das interações entre indústria- governo- universidade. Tais cenários mostrarão se é ou não propício, o nascimento de projetos inovadores, a partir do modelo Tríplice Hélice no estado de Pernambuco.

Palavras-chaves: Tríplice Hélice. Inovação. Universidade. Conhecimento. Simulador. Autômatos Celulares.

SUMMARY

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ACRONYMS

Acronym	Meaning
ANPEI	**National Association of Research in Industrial Companies**
CA	**Cellular Automaton**
CNI	**National Conference of Industry**
CPqD	**Center of Research and Development**
CSIC	**Webometrics Ranking Web of World Business**
CTA	**Brazilian Aerospace Technical Center**
EMBRAER	**Brazilian Aeronautics Company**
INPE	**National Institute of Space Research**
IT	**Information Technology**
ITA	**Aeronautics Technological Institute**
MDIC	**Ministry of Development Industry and Commerce**
MEC	**Merrimack Education Center**
UFMG	**Federal University of Minas Gerais**
UFPE	**Federal University of Pernambuco**
UFSCar	**Federal University of São Carlos**
UNICAMP	**University of Campinas**
US	**United States**
USP	**University of São Paulo**
WOM	**Word-of-Mouth**

1 INTRODUCTION AND MOTIVATION

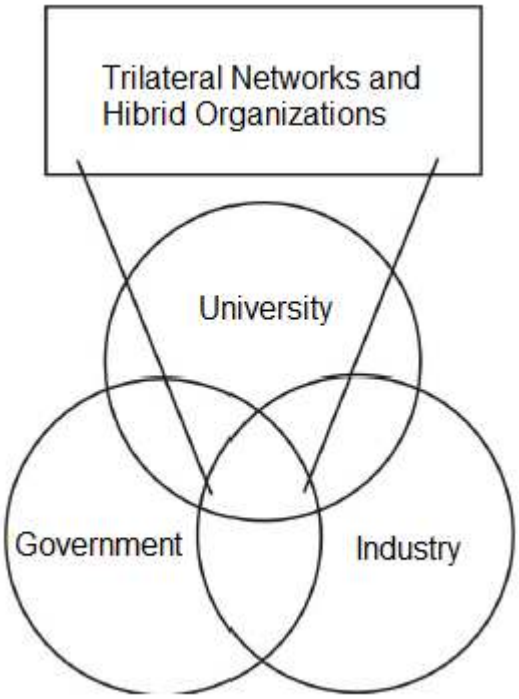
We live in a moment where huge and fast transformations take place in the entire world. These transformations are so dynamic that, in the space of few years, some technologies are totally obsolete and replaced by new ones. What is in the center of all this? The knowledge. Nowadays, institutions have placed the knowledge in the center of their innovation process.

Accordingly to Drucker (2003), one of the reasons for these transformations have started, is related with the education. He talks about the GI Bill of Rights which gives to every American soldier, which had gone back of the Second World War, the money to frequent the university. Accordingly to him: *"The GI Bill of Rights and the enthusiastic response to it on the part of America's veterans signaled the shift to a knowledge society. In this society, knowledge is the primary resource for individuals and for the economy overall."* (DRUCKER, 2003).

Inside the knowledge based economy, the innovation is essential to bring the dynamism to the market and encourage the increase of the companies' competitiveness. Not long time ago, it was discussed the role of the government and the industry in the innovation and entrepreneurship, nowadays, another factor has been discussed, the entrance of the universities as the main source of knowledge production, interacting with the government and companies. Innovation has been threatened as a complex result of interactions between the science, technology, and R&D inside the universities, industry and government. Several approaches have been proposed to better understand the innovation process (DRUCKER, 2003), (MAHDJOUBI, 1997). One of the most popular is named Triple Helix (LEYDESDORFF, 2000).

The triple helix model characterizes the innovation in a context where relations are established between three spheres: universities – industry – government and their interaction is the key to stimulate the innovation in a knowledge based economy.

Figure 1. Triple Helix Model



Font: Etzkowitz, 2002.

In the triple Helix Model, the successful interactions between the three components led to social projects as incubators and science parks. The role of the government is to promote social projects with the intent of stimulate the innovation inside the companies and universities. The university forms high skilled labor force, research and develop technologies, establish relation with the government and companies. The industry raises the man skills, develops innovative products and services and leads the changing process.

The Triple Helix is a public-private partnerships (PPP) evolutionary model. While the PPPs model encompasses the relations between the industry and the government in favor of society, the triple helix model includes one more component, the university, which brings the innovation and the knowledge to the projects. The relations between universities – industry – government are the result of three dimensions of the Triple Helix. The first one is the internal transformations in each helix, as an example, the relation between firms through a coalition. The second is the influence that one helix has on another, for

example, the R&D policy applied by the government on the universities and the third is the creation of new networks as the result of the interactions between the three helixes (ETZKOWITZ, 2002).

Each one of the Triple Helix components, have their competency as the following table demonstrates:

Table 1. Aspects of the Triple Helix Components. (Based on Abdalla et al., 2009).

Actor	Responsibility	Limitations
Government	1. Promote the economic development through new organizational structures 2. Hold political plans with governmental goals directed to innovation and knowledge. 3. Interact with several political spheres 4. Stimulate benefits to the population.	5. Over bureaucratization and lack of flexibility for implementation of partnership projects. 6. Necessity of professional and participatory public management
Industry	1. Development of innovative products and services. 2. Promote the interaction with the scientific community technology transfer center. 3. Lead the changing process.	4. Poor capacity of investment on innovation and technology development. 5. Academic and technological unpreparedness for research conduction.
University	1. Create new sources of technology and knowledge. 2. Establish relations with the companies and the government. 3. Create new areas of proceeding. 4. Lead the changing process	5. Dependency of incentive organ for the research realization. 6. Weak view of professional training and training manpower. 7. Weak ties with the society and industry.

Unlike other theories that focus on industry and government on the innovation process, the triple helix model focus on universities as the main source of entrepreneurship and technology. It is precisely in the universities that the knowledge is mainly produced in Latin America countries (PESQUISA UNIVERSITARIA E INOVAÇÃO NO BRASIL, 2007). However, in Brazil, the universities and the companies still have a weak relation. The companies can't keep up with the innovation created by the universities and still advance with older technologies and with human resources without the high skill that the universities can provide. Thus, the Triple Helix model is not yet consolidated in Brazil. The components of the model do not yet interact with each other as it was supposed to do. There is a gap between the technologies and the knowledge created in the universities and their adoption by the companies.

This lack of an articulated interaction between the companies and universities makes the government and the universities to create incentive programs in order to improve the change of knowledge between them, as RHAE (Brazilian Programme on Human Resources for Strategic Areas) from CNPq (National Counsel of Technological and Scientific Development). RHAE is a program that has the intent to stimulate the collaboration between the companies, universities and the research institutes and empower the human resources with other ways than academic training like extra courses and trainee programs, among others. This program had its first call in 2007, with R$ 20 million in resources to be applied in Brazilian northeast, north and Midwest with the intent to include researches with master and doctoral degree in the market. Another example is the Economic Subvention Program from FINEP (Brazilian Innovation Agency/Research and Projects Financing), which make available non-refundable public resources for innovative projects. In 2009, the program intends to apply R$ 450 million into these projects. In the last three bids the program has already provided about R$ 1 billion for more than 500 hundred projects (FINEP, 2009). Others examples of initiatives that could stimulate the triple helix model are listed below:

Table 2. Examples of contemporary initiatives for the implementation of Triple Helix in Brazil. (Based on Abdalla et al., 2009).

Type	Definition
Institutions in the universities in order to manage the contracts with the companies.	Entities linked with the universities which were created in order to supplement the bureaucratic process which difficult the researches surveys, in respect with the need of autonomy for the companies hiring for the realization of outsourcing.
Companies incubators	Planned and protected environment, propitious for the development of micro and small companies interested on investment on new projects. It is also a way of decrease the bankruptcy rate in micro and small companies.
Tech parks	Areas usually linked to an educational or research center, with infrastructure needed for the installation of productive companies based on research and technological development.
Technopolis	A set of strategic actions in order to transform a specific region or city in a technological innovation pole of a specific segment
technology transfer offices	The goal is to study the market viability for the technology developed inside the universities give support to its market launch.

In Pernambuco, the technological center named Porto Digital is an innovative project that was conceived from a Triple Helix Model. Located in Recife city, it is the result of the implementation of public policies in partnership with the private sector, universities and agencies. It has more than 120 institutions (among technology companies, specialized research and service institutions), with four thousand people working on it. This advanced center had a seed, most of its projects came from the universities of Pernambuco, mainly from the Federal University of Pernambuco (PORTO DIGITAL, 2009). The example in Fortaleza city, is the Instituto Atlântico technological center, which was founded in 2001 and has as the main goal, provide the society with technological and scientific solutions. With more than 150 employees it operates mainly in Telecommunications and Information Technology areas. This center was created in an association with great universities from Ceará as Federal University of Ceará and State University of Ceará (INSTITUTO ATLANTICO, 2009).The following are some examples of the Triple Helix in Brazil.

Table 3. Examples of Triple Helix in Brazil. (Based on Abdalla et al., 2009).

Case / Market Segment	Academic helix	Government Helix	Industry Helix	Spiral of the helix effects
SOFTEX PADCT PBQP/ Informatics and Technology	UNB/ COPPE/ UFRRJ TECSOFT	MDIC	Informatics groups, banking automation, public management, transports and telecommunications	Qualification for the training directed to the global competitiveness
Design of the first national microcomputer	PUC-RJ/ USP	Marine/ Digibrás	Several companies of national capital	Promotion of the computer Brazilian industry; Technology gain
CPqD / Telecommunications	UNICAMP	CPqD	Telecommunications equipments companies	Development of strategies for the telecommunication sector of the country

EMBRAER / Aviation	Euvaldo Lodi Institute	CTA/ INPE	National confederation of industry (CNI)	Subsidy for the creation of state companies for airplane fabrication

As the knowledge becomes an important factor for the social-economic development, it is natural that the university, as the main responsible for producing and transferring knowledge, be seen as an important actor in the innovation process.

When we talk about quality in education, the University of São Paulo (USP) is considered the forty-fourth world best university accordingly to the Webometrics Ranking Web of World Universities (CSIC, Spanish acronym). This university is also responsible for twenty eight percent of the Brazilian scientific production (USP, 2009) and it has registered, until the end of 2008, 664 patents and patents application (UFSCar, 2009). In addition, USP is, together with the State University of Campinas *(*UNICAMP) and the Federal University of Minas Gerais (UFMG), the three unique universities in the ranking of patent depositary between 1990 and 2000 (Póvoa, 2006).

Among others major Brazilian universities and Education Institutes is the Aeronautical Institute of Technology (ITA). ITA is a federal government institution dedicated to provide high level education and research in Science and Technology areas of interest to the aerospace sector in general, and especially to the Aeronautical Command (ITA, 2009). It is considered by the Merrimack Education Center (MEC) the second best education institute in Brazil (MEC, 2009). In addition accordingly to the Instituto Lobo, ITA is the Brazilian university that produces more scientific article per doctor, it has an average of 5,4 published surveys per doctor while the national average is 2,25. The same worth for the surveys produced per courses, while ITA courses have an average of 69,13, the national average is 25,06 (FOLHA DE SÃO PAULO, 2008).

As we can notice, prestigious universities, as UFPE and UFCE, are the academic helix of the institutions that were designed from a Triple Helix Model as Porto Digital and Insitituto Atlântico respectively. With this in mind, some goal questions are relevant:

How does the entrance of the universities in the Triple Helix Model can contribute to the innovation in industry?

What's the importance of the universities in the Triple Helix Model?

Which factors contribute for the universities improve their participation in the Triple Helix Model?

Hence, there is a need for the definition of guidelines so that the universities could better operate in the Helix. Some strategies have been taken in attempt to define these guidelines (ABDALLA et al). In addition, the study of characteristics of the factors which make an institution to be considered innovative, has acquired an epidemiological dimension (GLADWELL, 2000). In this last one, the innovation process is characterized by Epidemiological Laws and Rules of contamination and spread of disease. In which the spread and infection strengths are mapped in actors and organizational process. However, there is no scientific literature examining neither how the epidemic process can be mapped to the innovation process, nor which factors and parameters must be considerate when we want to characterize the innovation process in an organization.

Based on the problem presented above, we introduce the main objective of this work:

Implementing and analyzing epidemiological models making use of cellular automata to simulate scenarios of clusters of triple helix components based on academic institutions with the purpose of signal places of innovative behaviors.

1.1 Overview of the Proposed Solution

In order to accomplish the objective, presented in the previous section, this research project will investigate how the educational institutions',

interacting with the government and the industry, operate as a driving factor for the creation of institutions that came from a Triple Helix Model. The goal is to create and characterize innovation scenarios between clusters of educational institutions. Thus, parameters and indicators for the creation of the scenarios will be characterized. As a result, we expect to provide an initial set of guidelines and innovation indicators based on the results of the simulations to signal organizations that came from a Triple Helix Model. On the other hand, for the analysis of the scenarios, where the variables and the behavior are not well defined, as it is in this case, the scientific community makes use of computational models and simulators. For this survey, the cellular automata will be used as abstract machines of computational simulation. These machines have already been successfully used for modeling epidemiological systems of several kinds according to the following authors: Fu et al. 2002.; Xiscanoé (2008).

1.2 Statement of the Contributions

As a result of the work presented in this dissertation, the following contributions may be listed.

- A mathematical-computer model used in the simulation of epidemiological phenomenon in the innovation process in industry;
- Application of the epidemiology concept in the study of factors which stimulate the innovative behavior;
- A map of components' clusters from Triple Helix indicating the places propitious to have government, industry and academic activities, besides of innovative projects.

1.3 Organization of the dissertation

The reminder of the dissertation is organized as follows:

- **2 STATE OF THE ART** presents the definition of Cellular Automata, The Tipping Point Theory, a brief discussion about Innovation and finally, three surveys about Innovation Indicators are described briefly.
- **3 PROPOSED SOLUTION** presents the simulation environment where the solution was constructed, the Triple Helix layers, the creation of the cellular automata rules for this survey and finally the general findings.
- **4 CONCLUSIONS** introduce the summary of the findings, the works related to this survey and finally the future works.
- **REFERENCES** lists the references used in this dissertation.
- **APPENDIX A** contains the source code of the cellular automaton created during this survey.

2 STATE OF THE ART

This Chapter presents the State of the Art and it is divided in the following sections. Section 2.1 presents the concept of Cellular Automata. Section 2.2 illustrates the Tipping Point Theory through histories followed by a discussion on Innovation's topic with three authors, Peter Drucker, Christensen and Schumpeter in section 2.3. Finally, section 2.4 presents a brief description about three surveys on innovation indicator topic.

2.1 Cellular Automata

A model can be seen as the approximated representation of any real problem using a determined language (math, logic, geographic, physics, etc.) and respecting one or more theories. Models which represent math language are named mathematic model and can be represented by a set of equations and/or expressions. Constructing a model allow us to place the complexity of a real problem within a logic structure which can be analyzed. Thus, it is possible to evidence the alternatives of decisions and their possible effects, indicating relevant data and leading us to informative conclusions. The process of constructing models is called modeling. There are several techniques for math and computational modeling and lots of them have been used to represent epidemiological phenomenon.

The computational modeling consists in the utilization of computational abstract machines for the generation and inference of rules when the system to be modeled do not allow that the equations and math expressions be precision described or even estimated. The use of computational modeling is done together with the math modeling. This is because this last one is used when some behaviors of the modeling object are completely characterized in the behavioral and descriptive point of view.

The modeling of innovations phenomenon in industry is very recent in literature. The techniques used so far are based on statistician processes of predictability and inference. However, the behavior of the industry does not seem to obey previously defined rules. In this context, the use of computational abstract machines is important for the definition of innovation scenarios. The cellular automata can be used as abstract machines of computational simulation.

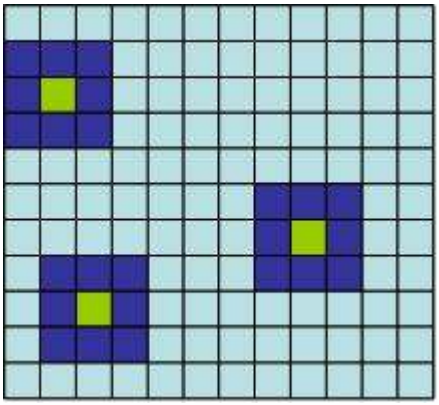
Cellular automata which represent dynamic systems, where the time and the space are discreet, have been used in the literature as computational models for object simulating including disease epidemiology (FU et al. 2002).

Formally, Cellular Automata are defined as the evolution of the cells' states which compose it. The state of a cell $\sigma_i^t \in \{0,1\}$ indicates that in the position *i* in the instant *t* the cell assume one of the defined states, in this case 0 or 1. Assuming an N-dimensional grid of cells, we have an N-dimensional Automaton. The evolution of the cells' states is given by a function, thus the evolution rule is defined as

$$\sigma_i^{t+1} = f\left(\sigma_{i-k}^t, \ldots, \sigma_i^t, \ldots, \sigma_{i+k}^t\right),$$

where *k* is the iteration index. The evolution rule is applied simultaneously in all cells. The state of a cell in the time *t+1* depends of the state of the *2k+1* cells in the instant *t*, which constitutes its neighborhood. The figure 2 introduces one of the possible neighborhood forms, known as Moore Neighborhood which is used in this survey.

Figure 2. Highlight of the Moore Neighborhood for three cells of a 2-Dimensional Cellular Automaton in an instant t



These systems are able to create the more varied solutions spaces, configuring scenarios of predictability. Thus, it is possible, with the assistance of a specialist on the subject, to filtrate these scenarios to guarantee reliable answers from the model. Nevertheless, when the set of variable is large, the degree of predictability might not collaborate for a practical application in which is desired to obtain strategic planning from the answers of these models. In addition, the computational time predicted to simulate these models can be a limited aspect when the set of scenarios become complex (OLIVEIRA et al. 2002).

The modeling of *Tipping Points* in innovation industry of IT is characterized as a modeling object without math rules. The application of Cellular Automata can provide behavioral scenarios and even scenarios of predictabilities of behavior if the rules and simulation environment allow it. This survey investigates this possibility.

2.2 The Tipping Point

The Tipping Point's (2000) theory came up with the idea that the social behavior can be mapped to an epidemic behavior, in other words, events like the ebb and flow of product sales, crime waves, fashion trend adoption must be treated as epidemics.

To understand this, we need to recognize that the social epidemic contain the same factors which operate on epidemics. These factors are the people who transmit infectious agents, the infectious agent itself, and the environment in which the infectious agent is operating.

Here, these factors are mapped in three rules, called respectively, *The Law of the Few*, *The Stickiness Factor* and *The Power of the Context* which are described in the following sections.

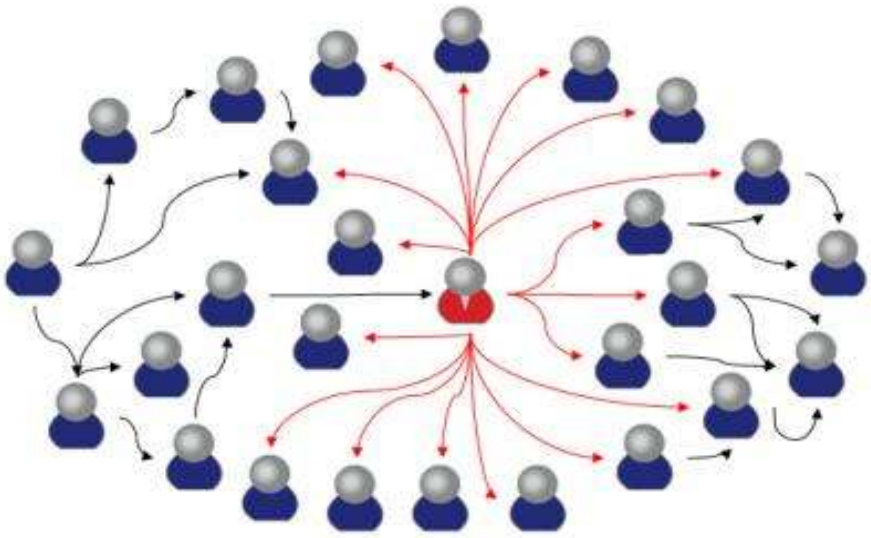
2.2.1 The Law of the Few

The success of any kind of social epidemics is extremely associated with the participation of people with a rare set of social gifts. *This is The Law of the Few,* which talks about those people who are able to start a social epidemic. They are called by The Tipping Point Connectors, Mavens, and Salesmen. The following are described this kind of people.

2.2.1.1 Connectors

Connectors are that kind of person who knows everyone. They have a lot of social connections and their circle of friendship is very large. Usually they are good communicators with a good facility of making friends and acquaintances.

Figure 3. Illustration of a Connector.



But the Connectors are not so important because they know a lot of people. They are important because they also know different kinds of people, and these friendships and acquaintanceships can bring them to occupy different cultures and niches.

Because of their great number of connections and their capacity to occupy many different worlds, they are people who we can reach only in a few steps. As a result, the Connectors play a big role in a social epidemic. When something like a product or message reach and are approved by someone like them, they are able to start a word-of-mouth epidemic.

2.2.1.2 Mavens

In a social epidemic, as well as there are people who connect you to others people, there are also people who connect you to information. These people are reading lovers with a great capacity to absorb information and accumulate knowledge. But not in a partial way, they are able to talk about products in the market, product prices and best places to find or buy something, everything in a good detail. That's the reason behind they are so important in the market. They are the people who know when there is something wrong with promotions and

when there is some kind of misleading advertising. They keep their eyes open about the market and if something is wrong they tell to everybody. They could connect the consumers to the market. They collect information and share with others people because they feel good in doing that, not because is their job or their task, it's their nature. These are the *Mavens*.

The reason behind the mavens are so important in a social epidemic is that they carry information that we don't. When someone, like a Connector, advices ten people about something, half of them might take the advice in consideration, but, when a Maven advices ten people about something, they have so authority to talk about it that all of them might consider his advice. Mavens and Connectors have different profiles. However, both of them could start social epidemics with their own skills.

2.2.1.3 Salesman

Despite Mavens have the great ability to help people with their knowledge, they lack the capacity of persuade this people. They could provide you with the amount of information they have, but, for a social epidemic to start, some people need to be convinced to do something, and they aren't the kind of people who wants to do that. This is when the *Salesman* comes up.

The salesman has a special way to talk with people. They are articulated and express very well their points. In a social epidemic, they prevent people to break the flux of the message by convincing them of their point of view. They are able to do that in an easier way than the rest of us.

2.2.2 The Stickiness Factor

Last chapter we talked about the influence the nature of the messenger has in starting a word-of-mouth epidemic. But, for a social epidemic to tip is not only the people that matter, the message matters too. If someone like a

connector starts to recommend a restaurant for his friends or acquaintances, the restaurant has to be good to make a good impression in the people who visit it. Otherwise, only the skills of a connector will not be sufficient in that case.

The capacity the message has to get in the people's mind is an important thing. In a w-o-m epidemic, the messages have a key characteristic. When they achieve people, they cause an impact. They have *The Stickiness Factor*, the second rule of epidemics.

For better illustrate what we are saying here, let's make an analogy with the HIV virus which circulated in the town of Harlen in the Dutch province of Limburg after the Second World War. This virus got into a hospital and was transmitted to a great number of children. But the strange thing is that only a third of the children died in consequence of the virus, the others get safe. These two thirds did something impressive, they defeat the HIV virus (GLADWELL, 2000).

Today this is almost impossible. The HIV virus which circulates nowadays is very different from that which circulates in the town of Harlen after the Second World War. That virus was very contagious but, weak enough for people get free of it. Whereas today, the HIV virus became deadlier, when you get infected, it stays with you by a large period of time.

This is how the message must be to tip an epidemic. Usually we spend a lot of time thinking how we can reach a large number of people with our ideas. But this idea can go in one ear and out the other. The Stickiness Factor makes the massage reach your mind and stay there. You can't get free of it.

2.2.3 The Power of the Context

The third rule of epidemics talks about the context where the epidemic happens. We, human beings, are more sensitive to the environment than we think. To illustrate this, the following is a passage withdrawn from (GLADWELL, 2000).

"One of the most infamous incidents in New York City history, for example, was the 1964 stabbing death of a young Queens woman by the name of Kitty Genovese. Genovese was chased by her assailant and attacked three times on the street, over the course of half an hour, as thirty-eight of her neighbors watched from their windows. During that time, however, none of the thirty-eight witness called the police. The case provoked rounds of self-recrimination. It became symbolic of the cold and dehumanizing effects of urban life."

It seems that two psychologists Bibb Latane from the Columbia University and John Darley from New York University demonstrated through an experiment, what looks to be the answer for why none of the witness helped Genovese in that moment. They had a student in a room stage an epileptic fit. When there were four people in the next door, listening that seizure, 38 percent of them helped the student. But, when there was only one person next door, for our surprise, the rate increases to 85 percent. The psychologists come to the conclusion that when we are in group, the responsibility of acting is shared among the others and we feel that we don't have the obligation to do something (GLADWELL, 2000).

This experiment is an example of how things can take a completely different course depending on the context in which they are happening. This is *The Power of the Context*. This rule is applicable in a social epidemic and it is not less important than the Stickiness Factor neither the Law of the Few.

2.3 Innovation

The following are presented the point of view of three authors about innovation. They are Schumpeter, Drucker and Christensen.

Schumpeter (1994) argues that the innovation radically changes the industry through a process which he named, Creative Destruction. According to him, the Creative Destruction is the process of replacement, over the time, of the old industries (destruction) by the new industries (creation). This process occurs with the forthcoming, on the market, of new and better products. These products

are so technological advanced that makes the older products to become antiquated and consequently, destroyed. Examples include the replacement of typewrites by the computers and the replacement of the workman by the machines in industry. For Schumpeter (1994, p. 83), the Creative Destruction *"incessantly revolutionizes the economy structure from within, incessantly destroying the old one incessantly creating a new one."* Therefore, Schumpeter believes that innovation is the opening up of new markets through the creation of new and better products.

Figure 4. Creative Destruction: Polaroid instant cameras were vanished with the forthcoming of digital cameras.

In Schumpeter's (1983, p. 66) theory, the entrepreneur is the responsible for promoting the innovation through the following five cases: (1) the introduction of a new product, like the cell phone. (2) The introduction of a new method of production, like the "Taylorism". (3) The opening of a new market, like the automotive industry. (4) The conquest of a new source of supply of raw materials. (5) The carrying out of the new organization of any industry, like the creation or the breaking up of a monopoly position.

At the same direction, Drucker (2007, p. 65) agrees with Schumpeterian model of creative destruction. He argues that *"the most productive innovation is a different product or service creating a new potential of satisfaction, rather than an improvement."* Thus, for Drucker, the creation and forthcoming of a product or service must be something different and must aggregate value to its consumers, in other words, it must has market value. At this direction, Drucker (2007, p. 66) stresses that innovation is different from invention which has a technological meaning and it is not traded in the market: *"innovation is not invention. It is a term of economics rather than of technology"*.

Drucker (2007) still points that for an invention becomes an innovation, there is a long way to run: *"for every dollar spent on generating an idea, ten dollars have to be spent on "research" to convert it into a new discovery or a new invention. for every ten dollars spent on "research", at least a hundred dollars need to be spent on development, and for every hundred dollars spent on development, something between a thousand and ten thousand dollars are need to introduce and establish a new product or a new business on the market. And only after a new product or a new business has been established in the market is there an "innovation""*.

Drucker (2003, p. 53) believes that the innovation plays a key role in the entrepreneurship. For him, *"innovation is the specific function of entrepreneurship. It is the means by which the entrepreneur either creates new wealth-producing resources or endows existing resources with enhanced potential for creating wealth."* According to Drucker, a person who opens a typical restaurant cannot be considerate an entrepreneur because this service is not an innovative service, it doesn't bring a new kind of satisfaction to its consumers.

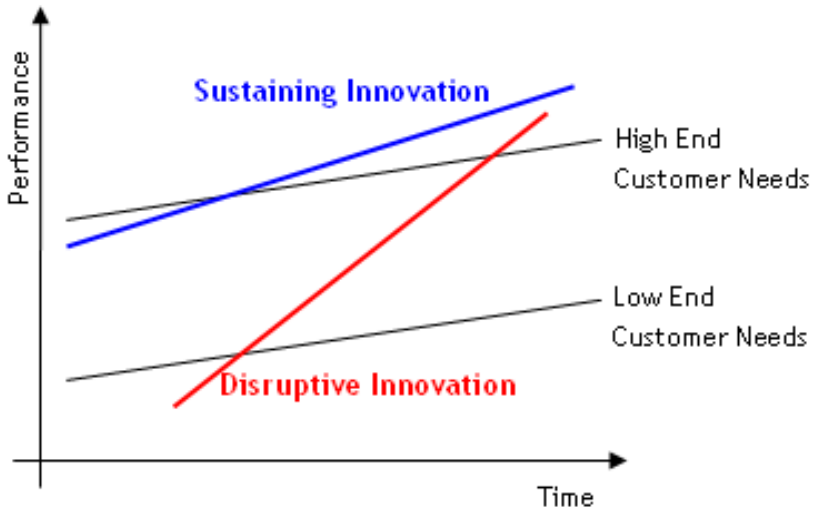
In this context, Christensen (1997, p. xv-xviii) calls Disruptive Innovation a new and simple product which brings to the market a new kind of satisfaction different from the one that had been available previously. For him, this product is usually cheaper, simpler and has less quality than the one in the current market. But, when these technologies become better and reach the level of satisfaction of the main consumers, they can invade the mainstream market. So, at the

beginning, it reaches the undemanding customers and then, after some time, it reaches the customers in the mainstream. We can take as examples of disruptive innovation the wireless handheld devices, like Blackberries, and Palm Pilots which are disruptive relative to notebook computers.

Christensen explains why he calls it Disruptive Innovation: *"I call that a disruptive innovation not because it's a breakthrough from a technological sense, but instead of sustaining the trajectory of improvement that has been established in a market, it disrupts it and redefines it by bringing to the market something that is simpler."* (FELLOW, 2004).

On the other hand, Christensen (1997, p. xv) also defends that innovation can be the improvement of established products on the market. He calls it Sustaining Innovation. *"Most new technologies foster improved product performance"*, says Christensen. As these products have a better quality, the companies can sell it for higher margins to its best customers. The sustaining technologies can have an incremental or a radical character, like the improvements on telecommunications, from analogical to digital and digital to optical. But Christensen (1997, p. xv) alerts, *"What all sustaining technologies have in common is that they improve the performance of established products."*

Figure 5. Disruptive and Sustaining Innovation's performance over the time.



The figure 5 illustrates that the Sustaining Innovation attract the mainstream market because of its better quality. While the Disruptive Innovation, which is simpler, takes root in an undemanding portion of the market and then, as it gets better, reaches the high end customer needs.

In sum, Schumpeter believes that the companies must, systematically, abandon the older and adopt the newer and better technologies to be successful. To him, every innovation implies in this process, which he named Creative Destruction. Like Schumpeter, Drucker believes that the innovation radically changes the economy with the forthcoming of different and better products which open new markets creating a new customer. On the other hand, Christensen's theory named Disruptive Innovation break with natural behavior of the established companies which invest in improved technologies for the existing customers. For him, simpler technologies deserve great attention by the established companies. That is because when these technologies become better and reach the level of satisfaction of the main consumers, they can occupy the mainstream market to compete with established companies.

Taking into account all the author's innovation definitions, for this survey, we will considerer innovation as the introduction of a new or improved product on the market by the companies. The new product must have different characteristics and can be simpler or more complex than the previously introduced products. Regarding to the improved product, this must provide a significant improvement in their performance.

2.4 Innovation Indicators

As the construction of a new class of indicators is considered a painful (it demands a lot of work and create a lot of discussion) and time-consuming (it might take years to validate the indicators) solution Rocha & Ferreira (2001), we decide to make use of consolidated indicators in industry. So, a literature

research was made to collect the set of indicators for this work. The next sections demonstrate a short pass between three surveys. The last two of them are best described in the Related Work section. The Oslo Manual (2005), which contains guidelines for the construction of innovation indicators, was the first work seen. After that, Rocha & Ferreira's (2001) work, that compare innovation between two groups of companies was the second step done. The third is the Michigan Department of Labor & Economic Growth's (2007) work, which compare the innovation strength between Michigan and others U.S. states. Finally, we present our set of innovation indicators.

2.4.1 The Oslo Manual

Many surveys about innovation indicators follow the instructions of the Oslo Manual when constructing indicators. Usually, they are studies about comparison on innovative capacity between companies or regions. The Oslo Manual is a document which provides guidelines for the construction of innovation indicators, giving detailed information about the way we must follow to construct our indicators. According to the Manual, the innovation indicators can be classified in qualitative or quantitative.

Qualitative data involves questions on whether or not firms have engaged in an innovation activity. Also are considered, questions related to the education level of the workforce, for example, how many people are involved with R&D activity. Quantitative data involves questions related to expenditures on firm innovation activities like the investment on research and development.

2.4.2 Analysis of Brazilian technological innovation indicators: comparing a group of privatized companies and a general group of companies

Rocha & Ferreira's (2001) developed a work about innovation indicators comparing two groups of companies. The comparative analysis was based on

innovation indicators, produced by the National Association of Research in Industrial Companies (ANPEI, 1999), which demonstrated more consistence during the period from 1994 to 1998. The methodology for constructing the indicators reflects the orientation of The Oslo Manual (2005). Three of the indicators are *the education level of the workforce*, *total investment on innovation* and *patents issued*.

The education level of the workforce measure the quantity of employees with higher education certificate or degree involved with R&D activity. This is important because highly educated employers demonstrate that the company has potential to develop innovation. The investment on innovation is related to expenditures the company has with, for example, the acquisition of machinery, training, license for use of patents, facilities, research and development. Finally, the number of patents reflects the number of products or services that have been created by the company.

2.4.3 Innovation Indicators – Report to the Council for Labor and Economic Growth

The Michigan Department of Labor & Economic Growth (2007) developed a survey about innovation indicator called *Innovation Indicators – Report to the Council for Labor and Economic Growth*. This survey compared the innovative strength between Michigan and others U.S states.

The innovation indicators selected were five. The three ones related before in the (Rocha, 2001) work and the next two: (1) Percentage of scientists and engineers in the workforce, which contribute for the development of new technologies. (2) Venture capital investment which is an important indicator because stimulates innovation allowing the investment on young firms.

According to the survey, these indicators measure the capacity for technological innovation and all of them were produced by a reliable source with a consistent methodology.

2.4.4 Innovation Indicators used in this Work

For the survey we decided to use three indicators that best fits this work. The Educational Level of the habitants will tell us how many graduated people we have in a region. The investment on innovation is related with the innovation programs which the government releases and the higher competition between companies in a region implicit tell us that a region is economically active, thus, it is an innovative region. Thus, taking this into account, for this survey, we chose three of them. The Following are the three indicators:

- Education Level of the habitants;
- Investment on Innovation;
- Competition between companies.

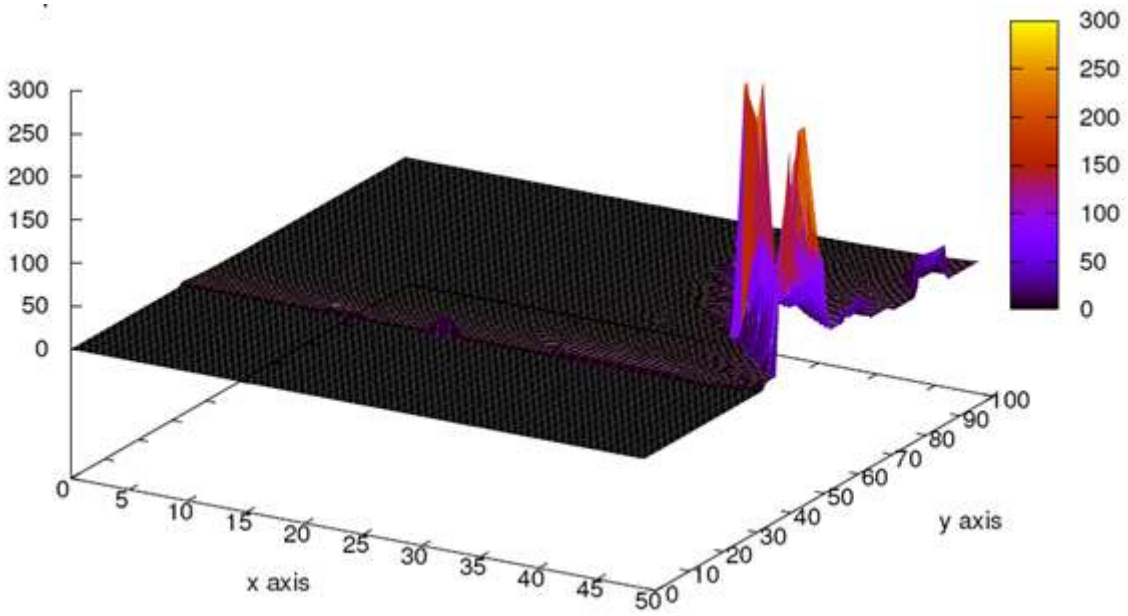
3 PROPOSED SOLUTION

The Triple Helix Theory came up with the idea that the successful interaction between the industry-government-university lead to innovative projects which contribute to the economic development in a region. As the knowledge becomes the most important factor in the innovation sphere, the base of the interaction between the three helixes has been the universities.

The solution proposed by this survey is a simulator that generates scenarios of interaction between the three helixes. In this simulation, we will investigate the behavior of the academic helix and provide an initial set of guidelines so that the university helix could better operate in the triple helix. As a result, we expect to see in the simulation, places where is propitious the born of projects that came from a triple helix model in the state of Pernambuco.

To make the simulations of the innovation scenarios, we will use the cellular automata model. In this model, we are able to construct the laws and rules of the interaction between the helixes. The reliability of the simulation is graduating achieved as long as we improve the laws and rules of the interaction of the helixes and also with the filter of the scenarios done by a specialist in the subject. In addition, a special attention must be paid to the great capacity that the cellular automata has on generating visual results. As the following figure demonstrate a screen shot of a 3D cellular automaton.

Figure 6. Representation of a Cellular Automaton in 3D

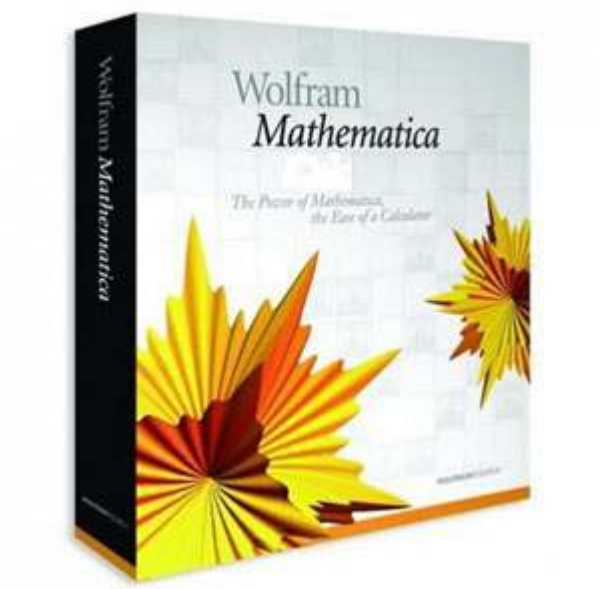


Next, we are going to introduce the proposed solution in detail. The section Simulation Environment is going to introduce us the software used to create the simulator followed by the section Designation of the modeled area which will show us which physical area was modeled. After that, the section Characterization of the Layers will demonstrate the four layers of the cellular automata model. Then, the section Creation of the Rules will introduce us with the rules that rule the simulation and finally, the General Findings will introduce us the conclusions of the work.

3.1 The Simulation Environment

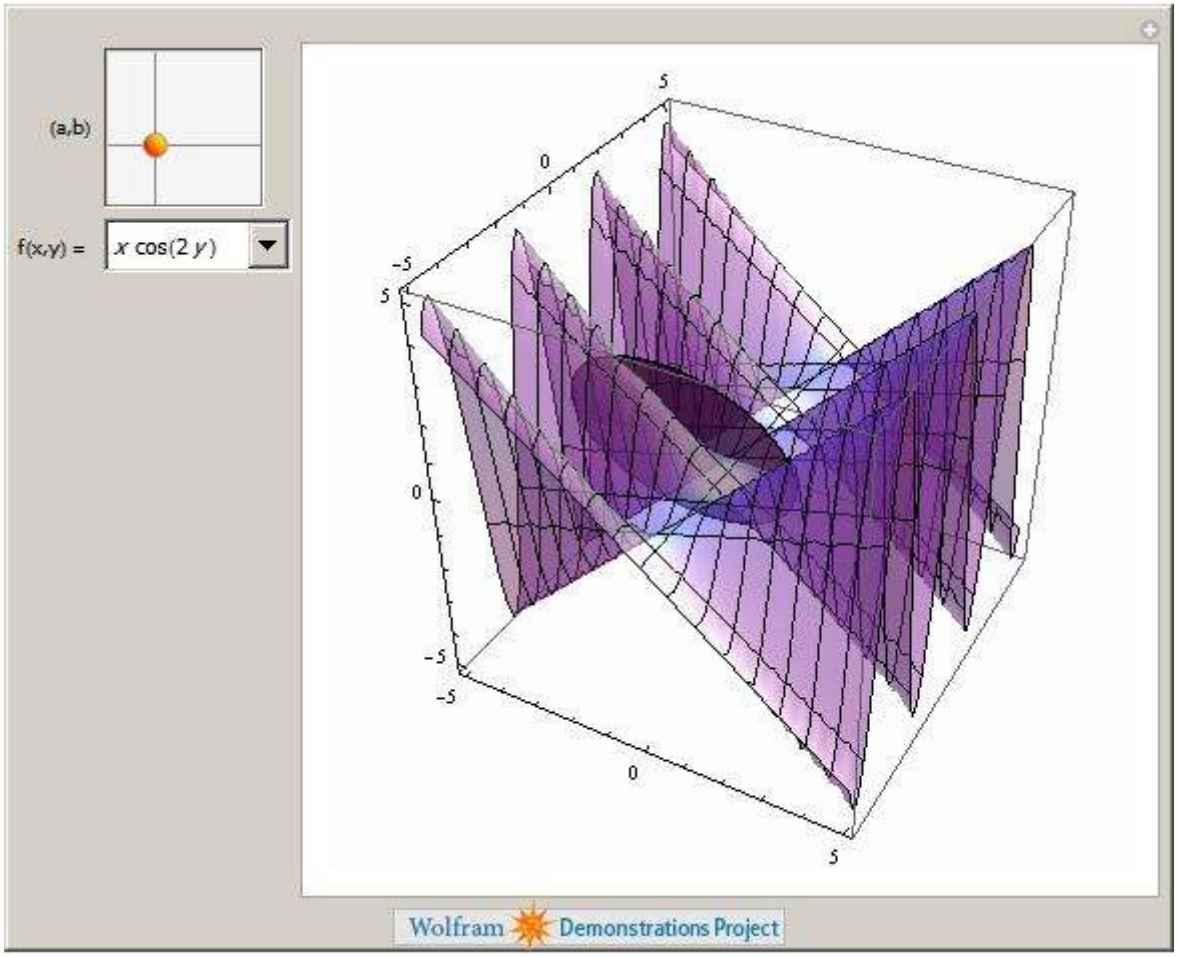
To make this experiment, we used a software called Wolfram Mathematica version 6. All the cellular automata rules developed, (more detail in next sections), were transformed in Mathematica Code to be compiled and run in this software. The processor used was an Intel I3 with Windows 7 and 4GB of ram memory.

Figure 7 Wolfram Mathematica



The Wolfram Mathematica is a technical and scientific software used in many areas as scientific, engineering, and mathematical. It was conceived by Stephen Wolfram and it is able to solve complex mathematical equations besides provides us with a rich graphic based on functions. Next, we can see a screen shot of a graphic generated by the Wolfram Mathematica.

Figure 8 3D Graph generated by Mathematica

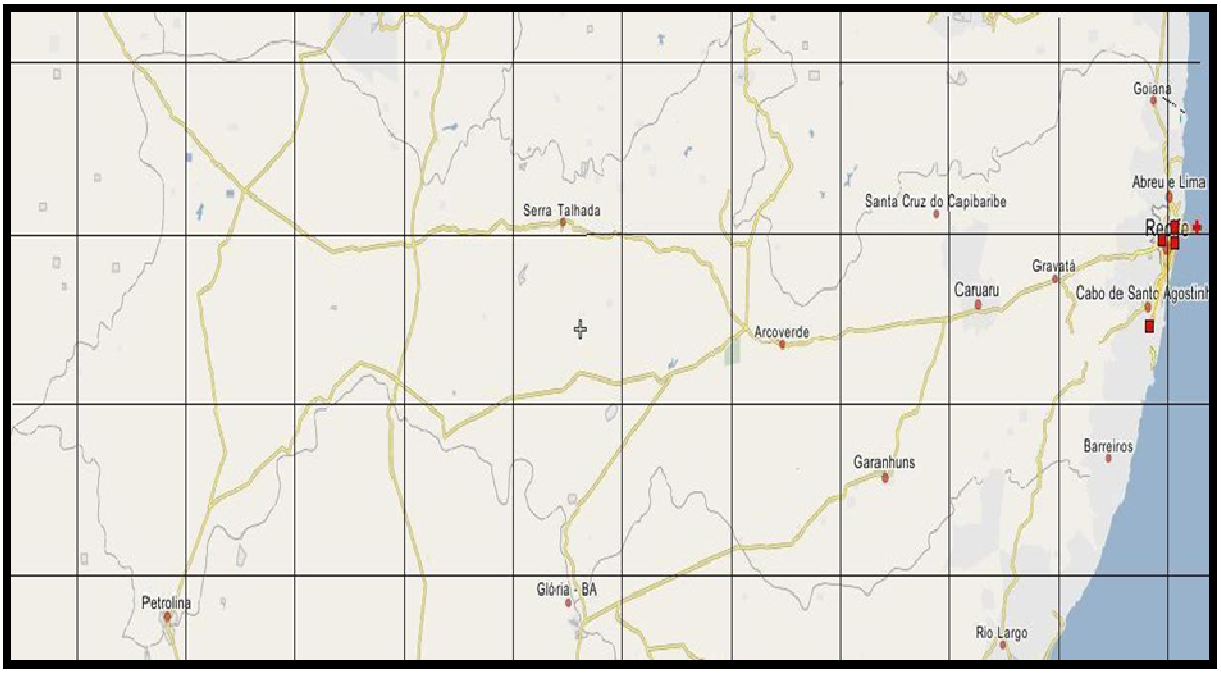


3.2 The Modeled Area

The area chosen for the experiment was the state of Pernambuco. First of all, we divided Pernambuco state in 48 cells, so it is possible to run the automaton in our environment in a good performance as we count with only one machine and the processor power is a restrict factor. Regarding to the physical area, to make the experiment, we decided to use one state (Pernambuco) because the triple helix model has government interaction and it is not common the government of one state interact with the government of another state to provide innovative projects. For example: the government of Pernambuco do not interact with government of Bahia or Ceará. Thus, the cells of Pernambuco state could not interact with the cells of Ceará state, so, it would be more difficult to

verify the birth of triple helixes institutions in the simulation. The figure 7 illustrates the map of the state of Pernambuco and how it is divided in 48 cells.

Figure 9. Map of Pernambuco state divided in 48 cells.



3.3 Characterization of the Layers

After the delimitation of the area, we are going to indentify where the presence of the Triple Helix's components (Government – Industry - Academia) are more effective in the map. This will be done answering question like, Where the presence of the Industry is more effective in the map? This question will be done related to the three Triple Helix's spheres (Government – Industry - Academia). For cells where that presence is more effective we are going to paint the cell, in the map, of a specific color corresponding to a Triple Helix component and say that it is an Active Cell (see next session for more detail about cell's state) otherwise the cell will have no color and it will be considered an Inactive Cell. Regarding to the color, Government is the red color, Industry is blue follow by the Academia with the green color. Next, we can see an illustration with the

picture of the three layers. And Figure 11 demonstrate how we are representing these layers in 3D in the software Wolfram Mathematica.

Figure 10. Illustration of the effective presence of Triple Helix components in the map.

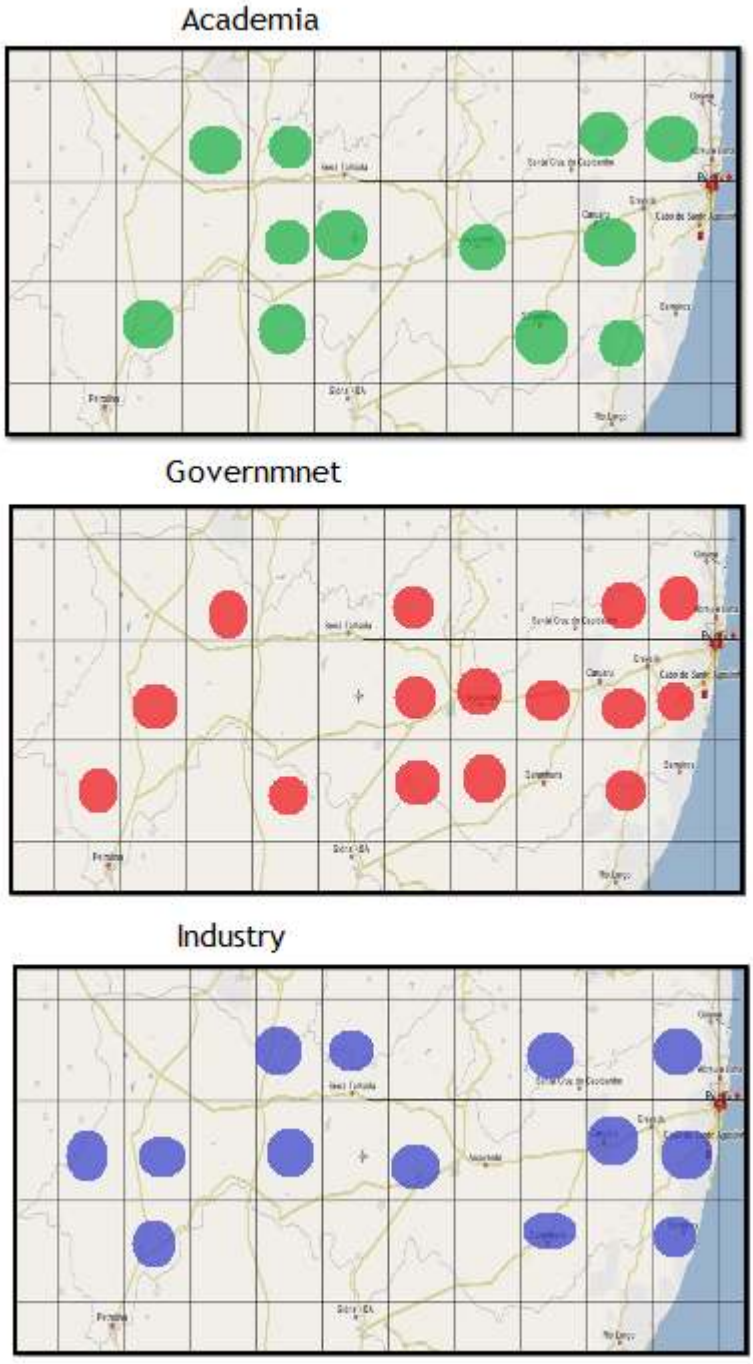
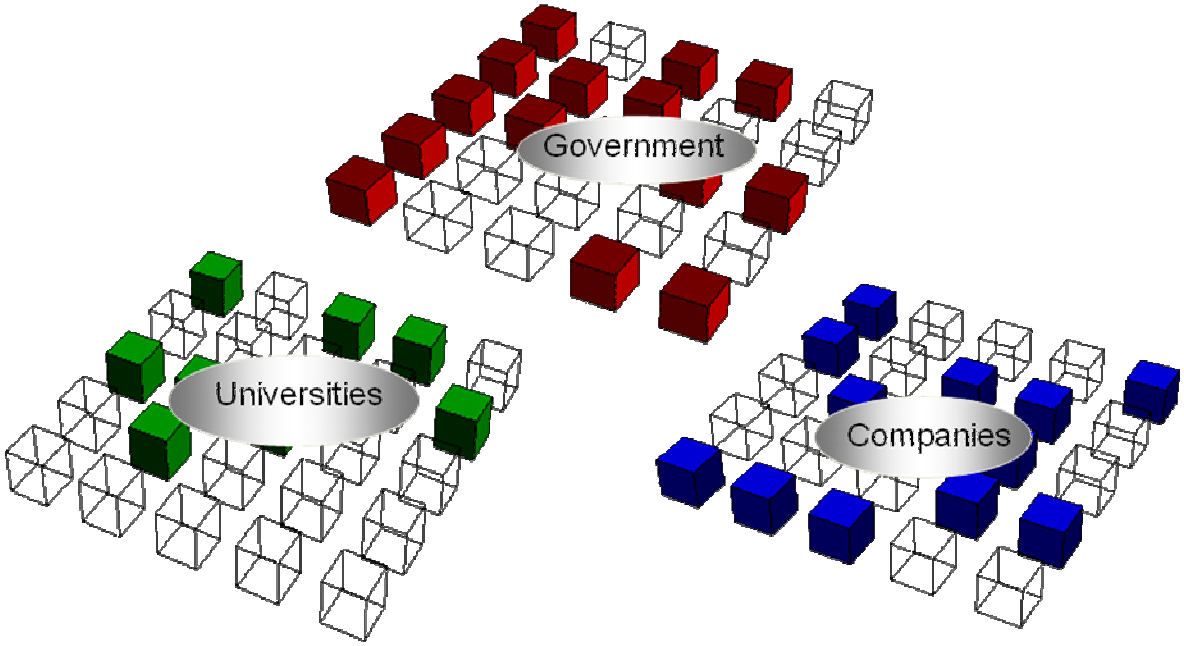


Figure 11 Representation of the three layers in the software Wolfram Mathematica.



3.4 Creation of the Cellular Automata Rules

The cellular automata rules will define the state of the cells through the interactions. The universe of this cellular automaton is an infinite three-dimensional grid of square cells, each of which is in one of two possible states, active or inactive. Every cell interacts with its eight neighbors, which are the cells that are directly horizontally, vertically, diagonally adjacent, above or below in its layer. At each step in time, the following transitions occur in each layer.

Industry Layer:

1. Any active cell with more than 50% of competition cells and fewer than two active neighbors becomes inactive, as if caused by under population.
2. Any active cell with more than 40% of competition cells and more than five active neighbors becomes inactive, as if by overcrowding.
3. Any active cell with more than 10% and fewer than 50% of competition and more than 3 and fewer than or equal to 5 becomes active on to the next generation.
4. Any inactive cell with exactly 10% of competition and 3 active neighbors becomes active on to the next generation.

Academic Layer:

1. Any active cell with more than 200 graduated people and fewer than three active neighbors becomes inactive, as if caused by underpopulation.
2. Any active cell with more than 2000 graduated people and more than seven active neighbors becomes inactive, as if by overcrowding.
3. Any active cell with more than 480 and fewer than 2001 graduated people and more than three and fewer than eight becomes active on to the next generation.
4. Any inactive cell with exactly 480 graduated people and 3 active neighbors becomes active on to the next generation.

Government Layer:

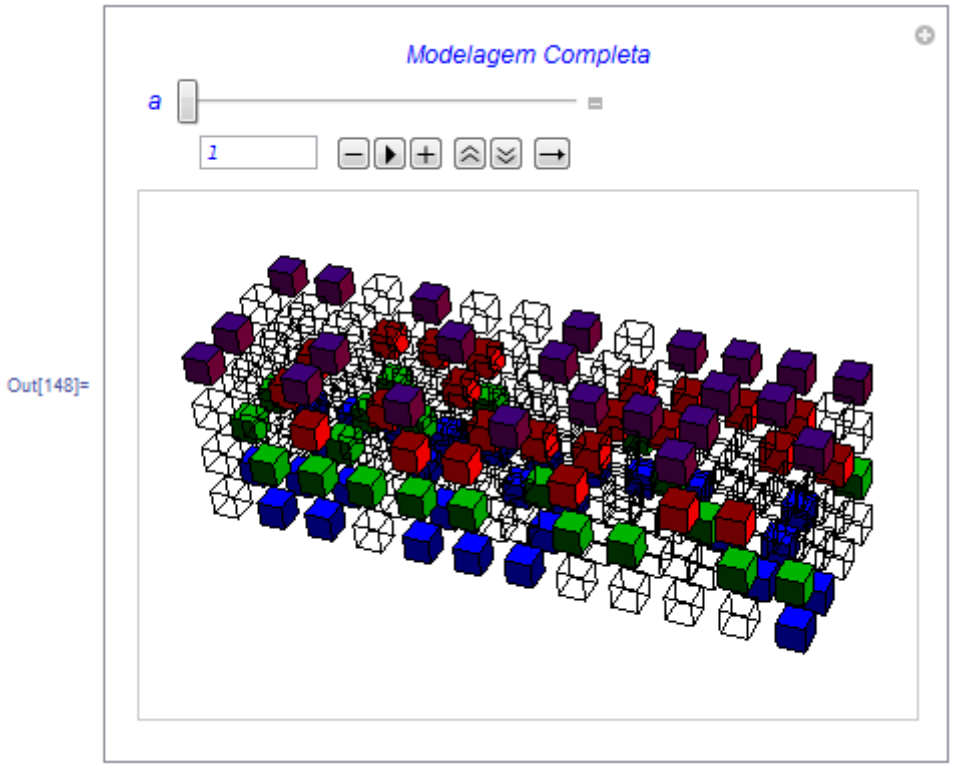
1. Any active cell with fewer than one innovation program and fewer than two active neighbors becomes inactive, as if caused by underpopulation.
2. Any active cell with fewer than two innovation programs and more than seven active neighbors becomes inactive, as if by overcrowding.
3. Any active cell with more than one and fewer than six innovation programs and more than two and fewer than eight active neighbors becomes active on to the next generation.
4. Any inactive cell with exactly one innovation program and two active neighbors becomes an active cell.

As we might see, for the industry layer, we used the competition indicator to indicate there is an economic activity in the cell. When this indicator show us a rate between 10% and 50% of competition between the companies of a region and more than three and fewer or equal to five active cells in its neighborhood becomes an active cell in next interaction. For the Academic Layer, we used the Educational Level of the habitants, to be more specific we paid a special attention to the graduated habitants of the region. As the Federal University of Pernambuco has graduated about 23.000 students in 2008 INEP (2010), we divided this number by the 48 cells that we had divided the Pernambuco state and this returned an average of 480 people graduated per cell. As we might see in the rules, this is the smallest value that a cell in the Academic layer must assume to become an active cell. In the Government Layer, the numbers of innovation programs that the government releases is the indicator for the cells of this layer become active.

The initial pattern constitutes the seed of the system. The first generation is created by applying the above rules simultaneously to every cell in the seed—

births and deaths happen simultaneously, and the discrete moment at which this happens is sometimes called a tick (in other words, each generation is a pure function of the one before). The rules continue to be applied repeatedly to create further generations. Next, we can see a screenshot of the initial cell's state of our cellular automata.

Figure 12 Screen shot of the initial setting of the cellular automaton

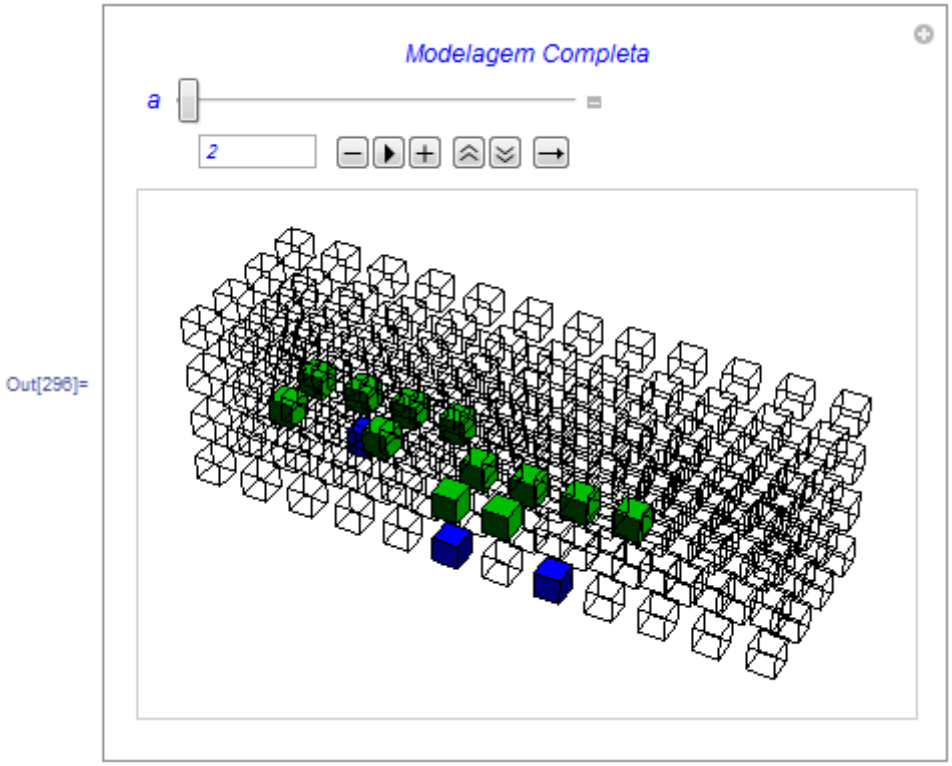


To create de rules mentioned before, it was done a research on databases of the academic sphere and Industry. Data related to Education could be fine in a rich way in the www.inep.gov.br website. This is the Brazilian National Institute for Educational Research and Studies which has as a mission, promoting studies, research and evaluations about the Brazilian Educational System with the objective of supporting the formulation and implementation of public policies for educational area based on parameters of quality and equity, as well as producing clear and reliable information to managers, researches, educators and the general public (INEP 2010). Regarding to the Industry sphere, this one demonstrate to be a difficult area to collect information in Brazilian databases. Few surveys like Rocha & Ferreira (2001) were found, which demonstrate data related to companies in

Brazil. But, no relevant data, to this survey, as the born rate of companies in the last years or the companies' bankruptcy rate, were found. Thus, due to the short time took to develop the survey and the difficulty to find a database with real data related to industry, all the rules created in each layer have fiction data.

In the next interaction, we might see a wide range of dead cells for all layers, represented by the transparent cells. This might occur due to the fact that the rules are not yet consolidate enough to maintain an equilibrium between the born and death of the cells. As the rules are refined and improved the model gains consistence and fidelity.

Figure 13 Screen shot of the second interaction of the cellular automaton



3.5 General Findings

It is possible to study the innovation behavior in a determined area through the epidemiological models based on cellular automata. However, it is important to have a great historic based on real data so the rules created could reflect a real close scenario of the situation. Regarding to data related to the educational sphere in Brazil, this demonstrates to be large, cooperating for the fidelity of the model. The INEP's website www.inep.gov.br, provides us with a wide variety of data related to students, teachers and the high degree in a general way. But, regarding to data related to industry in Brazil, this one demonstrated to be insufficient. We encountered and enormous difficult to find data related to companies rate bankruptcy and investments on innovation.

Regarding to the model, the cellular Automata demonstrated to be a model of easy implementation. The creation of simple rules and the transformation in Mathematica code showed us that there is no need for a specific knowledge or an extended study in the subject to construct the model.

4 CONCLUSIONS

The next sections present the conclusions of this work. In the section 4.1 we present a summary of the conclusions, the section 4.2 shows two works related to this survey followed by the section 4.3 which introduce us with the future works.

4.1 Summary of the Findings

The using of cellular automata to create a mathematical-computer model used in the simulation of epidemiological phenomenon in the innovation process in industry and the application of the epidemiology concept in the study of factors which stimulate the innovative behavior, could provides us a way of predict propitious places to have government, industry and academic activities and then, a way of predict where innovative projects could arise resulting from the interaction of the three Triple Helix components in a region.

4.2 Related Work

Two works were indentified based on a research in the innovation indicators topic. The first one we are going to describe is an international work called *The Innovation Indicators – Report to the Council for Labor and Economic Growth*. The second one is a national work called *Analysis of Brazilian technological innovation indicators: comparing a group of privatized companies and a general group of companies.*

In August 2007, the Michigan Department of Labor & Economic Growth (2007) published a work which describes an overview of the Michigan Innovation strengths and weakness related to others U.S. states. Five indicators were taken to classify the innovative potential of each state of the survey. These indicators are easy to understand and are organized in five sections, each one describing one indicator and the outcomes the survey reached with it. The outcomes are demonstrated through statistical data and with this information we can see the

situation of the Michigan State related to others U.S. states. Also, it is possible to have an idea, using the statistical data presented, of the innovation scenario of the Michigan state in a short future.

At this direction, Rocha & Ferreira (2001) developed a work which compares the innovative performance between a group of public companies and a group of privatized companies. The innovation indicators used in this work are consolidated and created with the consistent methodology of the Oslo Manual. As this work makes use of companies in the experiment, it is more similar to the work proposed here, as this one makes use of companies in its experiment too.

The statistical outcomes provided allow us to take conclusions about the innovation scenarios in the two groups of companies. But again, if we want to make any predictions about future innovation, we have to make deductions using the statistical data provided by the work.

At this context, the main advantage the work proposed here has related with the two works mentioned before, is the use of Cellular Automata for the innovation scenarios' predictions. Cellular Automata are very powerful at this context because they are simple to implement and because of their capacity to generate a range of scenarios of predictability which can be filtered with the assistance of a specialist in the subject in order to guarantee more reliability in the scenarios. As there is no work, in the literature, similar to the one proposed here, it is important to mention this is a pioneer survey.

4.3 Future Works

The next steps of the study case consist in the improvement and a more extensible study of the laws and rules that allow the three layers (university-government-companies) interact with each other in a more equilibrate way.

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APPENDIX A – Source code of the cellular automaton created in this survey.

```
(*Define largura e altura das matrizes*)

largura=12;

altura=4;

(*quantidades de niveis governo,empresa,educacao,inovacao*)

niveis=4;

(*Matriz para dados de Inovacao resultado final *)

MatrizInovacaoEstadosApresentacao=
Array[MatrizInovacaoEstadosCalculos,{largura,altura}];

MatrizInovacaoQuantidadeVizinhosApresentacao=
Array[MatrizInovacaoQuantidadeVizinhosCalculos,{largura,altura}];


(*Matriz para dados de Empresas*)

MatrizEmpresasEstadosApresentacao=
Array[MatrizEmpresasEstadosCalculos,{largura,altura}];

MatrizEmpresasQuantidadeVizinhosApresentacao=
Array[MatrizEmpresasQuantidadeVizinhosCalculos,{largura,altura}];

MatrizEmpresasConcorrenciaApresentacao=
Array[MatrizEmpresasConcorrenciaCalculos,{largura,altura}];

MatrizEmpresasConcorrenciaBufferApresentacao=
Array[MatrizEmpresasConcorrenciaBufferCalculos,{largura,altura}];


(*Matriz para dados de Educacao*)

MatrizEducacaoEstadosApresentacao=
Array[MatrizEducacaoEstadosCalculos,{largura,altura}];

MatrizEducacaoQuantidadeVizinhosApresentacao=
Array[MatrizEducacaoQuantidadeVizinhosCalculos, {largura,altura}];

MatrizEducacaoQuantidadePessoasFormadasApresentacao=
Array[MatrizEducacaoQuantidadePessoasFormadasCalculos, {largura,altura}];
```

```
MatrizEducacaoQuantidadePessoasFormadasBufferApresentacao=
Array[MatrizEducacaoQuantidadePessoasFormadasBufferCalculos, {largura,altura}];

(*Matriz para dados de Governo*)

MatrizGovernoEstadosApresentacao=
Array[MatrizGovernoEstadosCalculos,{largura,altura}];

MatrizGovernoQuantidadeVizinhosApresentacao=
Array[MatrizGovernoQuantidadeVizinhosCalculos,{largura,altura}];

MatrizGovernoQuantidadeProgramasFomentoInovacaoApresentacao=
Array[MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos,{largura,altura}];

MatrizGovernoQuantidadeProgramasFomentoInovacaoBufferApresentacao=
Array[MatrizGovernoQuantidadeProgramasFomentoInovacaoBufferCalculos,{largura,altura
}];


(*Funcao que inicializa a Matriz para Quantidade de Vizinhos com zero em todos os
elementos*)

InicializarMatrizQuantidadeVizinhos[matrizQuantidadeVizinhosCalc_,
matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w = matrizLargura, h =
matrizAltura },

        For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

            For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                matrizQuantidadeVizinhosCalc[passoX,passoY ]=0;

            ]

        ]

    ]

(*Funcao que inicializa a Matriz de Estados com zero ou um, aleatoriamente em
todos os elementos*)

InicializarMatrizEstados[matrizEstadosCalc_,
matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w = matrizLargura, h =
matrizAltura },

        For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

            For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                matrizEstadosCalc[passoX,passoY ]=Random[Integer];
```

```
                ]

            ]

        ]
```

(*Funcao que inicializa a Matriz de Concorrencia das Empresas com faixa entre zero a cem, em todos os elementos, para representar porcentagens*)

```
InicializarMatrizEmpresasConcorrencia[matrizEmpresasConcorrenciaCalc_,
matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w = matrizLargura, h =
matrizAltura },

            For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

                For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                    matrizEmpresasConcorrenciaCalc[passoX,passoY
]=Random[Integer,{0,100}];

                ]

            ]

        ]
```

(*Funcao que inicializa a Matriz Educacao, Quantidade de Pessoas, com faixa entre zero a dois mil, em todos os elementos, para representar o numero de formandos*)

```
InicializarMatrizEducacaoQuantidadePessoasFormadas[matrizEducacaoQuantidadeP
essoasFormadasCalc_, matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w =
matrizLargura, h =  matrizAltura },

            For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

                For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,


        matrizEducacaoQuantidadePessoasFormadasCalc[passoX,passoY
]=Random[Integer,{0,2000}];

                ]

            ]

        ]
```

(*Funcao que inicializa a Matriz de Concorrencia das Empresas com faixa entre zero a cinco, em todos os elementos, para representar quantidade de programas de investimento*)

```
InicializarMatrizGovernoQuantidadeProgramasFomentoInovacao[matrizGovernoQu
antidadeProgramasFomentoInovacaoCalc_,
```

```
matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w = matrizLargura, h =
matrizAltura },

                For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

                        For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,


        matrizGovernoQuantidadeProgramasFomentoInovacaoCalc[passoX,passoY
]=Random[Integer,{0,5}];

                    ]

                ]

            ]

        (*Funcao que retorna a quantidade de vizinhos ativos*)

        ContarNumeroVizinhos [meuX_, meuY_, matrizEstados_,
matrizEstadosLargura_,matrizEstadosAltura_ ]:=Module[{auxX=0,auxY =0, quantidade=0,
passoX=1,passoY=1},

                For[passoX =-1, passoX ≤ 1, passoX=passoX+1,

                    auxX = meuX+passoX;

                    For[passoY =-1, passoY ≤ 1, passoY = passoY +1,

                        auxY = meuY+passoY;

                        If[(auxY ≥ 1 && auxY ≤ matrizEstadosAltura ) && (auxX ≥1
&& auxX ≤ matrizEstadosLargura),

                            quantidade= quantidade + matrizEstados[auxX, auxY];

                        ,

                            quantidade = quantidade +0

                    ];

                ]

            ]

            quantidade = quantidade - matrizEstados[meuX, meuY];

            Return[quantidade];

        ]
```

```
(*Funcao que retorna a media de concorrencias das empresas da vizinhanca*)

CalcularMediaEmpresasConcorrencia [meuX_, meuY_,
matrizEmpresasConcorrencia_, matrizLargura_,matrizAltura_ ]:=Module[{auxX=0,auxY
=0, quantidade=0, passoX=1,passoY=1, amostra=0},

        For[passoX =-1, passoX ≤ 1, passoX=passoX+1,

            auxX = meuX+passoX;

            For[passoY =-1, passoY ≤ 1, passoY = passoY +1,

                auxY = meuY+passoY;

                If[(auxY ≥ 1 && auxY ≤ matrizAltura) && (auxX ≥1 &&
auxX ≤ matrizLargura),

                    amostra++;

                quantidade=(quantidade +
matrizEmpresasConcorrencia[auxX, auxY]);

                ,

                    quantidade = quantidade +0

            ];

        ]

    ]

     quantidade = ( quantidade/amostra); (*dividimos pela area 3x3*)

      Return[quantidade];


  ]

(*Funcao que retorna a media da quantidade de pessoas formadas da vizinhanca*)

CalcularMediaQuantidadePessoasFormadas [meuX_, meuY_,
matrizEducacaoQuantidadePessoasFormadas_, matrizLargura_,matrizAltura_
]:=Module[{auxX=0,auxY =0, quantidade=0, passoX=1,passoY=1, amostra=0},

        For[passoX =-1, passoX ≤ 1, passoX=passoX+1,

            auxX = meuX+passoX;

            For[passoY =-1, passoY ≤ 1, passoY = passoY +1,
```

```
                    auxY = meuY+passoY;

                    If[(auxY ≥ 1 && auxY ≤ matrizAltura ) && (auxX ≥1 &&
auxX ≤ matrizLargura),

                        amostra++;

                    quantidade=(quantidade +
matrizEducacaoQuantidadePessoasFormadas[auxX, auxY]);

                    ,

                        quantidade = quantidade +0

                ];

            ]

        ]

         quantidade = ( quantidade/amostra); (*dividimos pela area 3x3*)

         Return[quantidade];

    ]

    (*Funcao que retorna a media de concorrencias das empresas da vizinhanca*)

    CalcularMediaGovernoProgramasFomentoInovacao [meuX_, meuY_,
matrizGovernoProgramasFomentoInovacao_, matrizLargura_,matrizAltura_
]:=Module[{auxX=0,auxY =0, quantidade=0, passoX=1,passoY=1, amostra=0},

         For[passoX =-1, passoX ≤ 1, passoX=passoX+1,

            auxX = meuX+passoX;

            For[passoY =-1, passoY ≤ 1, passoY = passoY +1,

                auxY = meuY+passoY;

                If[(auxY ≥ 1 && auxY ≤ matrizAltura ) && (auxX ≥1 &&
auxX ≤ matrizLargura),

                    amostra++;

                quantidade=(quantidade +
matrizGovernoProgramasFomentoInovacao[auxX, auxY]);

                ,

                    quantidade = quantidade +0
```

```
                    ];
                ]
            ]
            quantidade = (quantidade/amostra); (*dividimos pela area 3x3*)
            Return[quantidade];
        ]
    (*Funcao que retorna o proximo estado da Matriz de estado Inovacao*)
    DefinirInovacaoProximoEstado[ estadoEmpresa_, estadoEducacao_,
estadoGoverno_]:=Module[{novoEstado=0},
                    If[((estadoEmpresa == 1) && (estadoEducacao == 1)
&& ( estadoGoverno == 1)) ,novoEstado=1;,(*ativado*)
                        novoEstado= 0 (*desativado*)
                    ];
            Return[novoEstado];
        ]
    (*Funcao que retorna o proximo estado da Matriz de estado Empresas*)
    DefinirEmpresasProximoEstado[meuEstadoEmpresas_, quantidadeVizinhos_,
concorrenciaMedia_]:=Module[{novoEstado=0},
            If[((meuEstadoEmpresas == 1) && (quantidadeVizinhos ≤1)) &&
(concorrenciaMedia >50),novoEstado=0,(*desativa por solidao*)
                If[((meuEstadoEmpresas == 1) && (quantidadeVizinhos >5)) &&
(concorrenciaMedia >40),novoEstado=0,(*desativa por sufoco*)
                    If[((meuEstadoEmpresas == 0) && (quantidadeVizinhos
==3)) && (concorrenciaMedia == 10),novoEstado=1,(*ativar*)
                        If[((meuEstadoEmpresas == 1) &&
(quantidadeVizinhos >3 && quantidadeVizinhos <=5)) && (concorrenciaMedia >10 &&
concorrenciaMedia <=50),novoEstado=1;,(*ativado*)
                            novoEstado= 0
                        ];
                ];
```

```
                ];

            ];

              Return[novoEstado];

        ]

    (*Funcao que retorna o proximo estado da Matriz de estado ConcorrenciaBuffer*)

    DefinirConcorrenciaBufferProximoEstado[meuEstadoEmpresas_,MatrizEmpresasCo
ncorrenciaCalculos_,MatrizEmpresasQuantidadeVizinhosCalculos_,MatrizEducacaoQuanti
dadePessoasFormadasCalculos_]:=Module[{novoEstado=0},

      If[((meuEstadoEmpresas ==1)&&(MatrizEmpresasConcorrenciaCalculos
<80))&&(MatrizEducacaoQuantidadePessoasFormadasCalculos>480),novoEstado=70,If[((
meuEstadoEmpresas ==1)&&(MatrizEmpresasConcorrenciaCalculos
<30))&&(MatrizEducacaoQuantidadePessoasFormadasCalculos>1000),novoEstado=80,If[((
meuEstadoEmpresas ==
0)&&(MatrizEmpresasConcorrenciaCalculos>20))&&(MatrizEducacaoQuantidadePessoasF
ormadasCalculos<480),novoEstado=70,

        If[((meuEstadoEmpresas ==
0)&&(MatrizEmpresasConcorrenciaCalculos>70))&&(MatrizEducacaoQuantidadePessoasF
ormadasCalculos<80),novoEstado=80,

        ];];];];

    Return[novoEstado];]



    (*Funcao que retorna o proximo estado da Matriz de estado Educacao*)

    DefinirEducacaoProximoEstado[meuEstadoEducacao_, quantidadeVizinhos_,
pessoasFormadasMedia_]:=Module[{novoEstado=0},

          If[((meuEstadoEducacao == 1) && (quantidadeVizinhos ≤2)) &&
(pessoasFormadasMedia ≤200),novoEstado=0,(*desativa por solidao*)

              If[((meuEstadoEducacao == 1) && (quantidadeVizinhos >7)) &&
(pessoasFormadasMedia >2000),novoEstado=0,(*desativa por sufoco*)

                  If[((meuEstadoEducacao == 0) && (quantidadeVizinhos
==3)) && (pessoasFormadasMedia == 480),novoEstado=1,(*ativar*)

                      If[((meuEstadoEducacao == 1) &&
(quantidadeVizinhos >3 && quantidadeVizinhos ≤7)) && (pessoasFormadasMedia >480
&& pessoasFormadasMedia ≤2000),novoEstado=1;,(*ativado*)
```

```
                                        novoEstado= 0

                                    ];

                                ];

                            ];

                        ];

                          Return[novoEstado];

                    ]

                (*Funcao que retorna o proximo estado da Matriz de estado
PessoasFormadasBuffer*)

                DefinirPessoasFormadasBufferProximoEstado[meuEstadoEducacao_,
MatrizEducacaoQuantidadePessoasFormadasCalculos_,
MatrizEducacaoQuantidadeVizinhosCalculos_,MatrizEmpresasConcorrenciaCalculos_]:=M
odule[{novoEstado=0},

                  If[((meuEstadoEducacao
==1)&&(MatrizEducacaoQuantidadePessoasFormadasCalculos
<1000))&&(MatrizEducacaoQuantidadeVizinhosCalculos<5),novoEstado=1000,

                   If[((meuEstadoEducacao
==1)&&(MatrizEducacaoQuantidadePessoasFormadasCalculos
<480))&&(MatrizEducacaoQuantidadeVizinhosCalculos<2),novoEstado=480,

                     If[((meuEstadoEducacao ==
0)&&(MatrizEmpresasConcorrenciaCalculos>480))&&(MatrizEducacaoQuantidadePessoas
FormadasCalculos>2),novoEstado=1000,If[((meuEstadoEducacao ==
0)&&(MatrizEmpresasConcorrenciaCalculos>1000))&&(MatrizEducacaoQuantidadePessoa
sFormadasCalculos>5),novoEstado=480,

                        ];];];];

                  Return[novoEstado];]




                (*Funcao que retorna o proximo estado da Matriz de estado Governo*)

                DefinirGovernoProximoEstado[meuEstadoGoverno_, quantidadeVizinhos_,
fomentoInovacaoMedia_]:=Module[{novoEstado=0},

                        If[((meuEstadoGoverno == 1) && (quantidadeVizinhos ≤1)) &&
(fomentoInovacaoMedia < 1),novoEstado=0,(*desativa por solidao*)
```

```
                    If[((meuEstadoGoverno == 1) && (quantidadeVizinhos >7)) &&
(fomentoInovacaoMedia < 2),novoEstado=0,(*desativa por sufoco*)

                        If[((meuEstadoGoverno == 0) && (quantidadeVizinhos ==2))
&& (fomentoInovacaoMedia == 1),novoEstado=1,(*ativar*)

                            If[((meuEstadoGoverno == 1) && (quantidadeVizinhos
>2 && quantidadeVizinhos ≤7)) && (fomentoInovacaoMedia >1 &&
fomentoInovacaoMedia <=5),novoEstado=1;,(*ativado*)

                                novoEstado= 0

                            ];

                        ];

                    ];

                ];

                Return[novoEstado];

            ]

        (*Funcao que retorna o proximo estado da Matriz de estado
FomentoInovacaoBuffer*)

        DefinirFomentoInovacaoBufferProximoEstado[meuEstadoGoverno_,MatrizGoverno
QuantidadeProgramasFomentoInovacaoCalculos_,
MatrizGovernoQuantidadeVizinhosCalculos_,
MatrizEducacaoQuantidadePessoasFormadasCalculos_]:=Module[{novoEstado=0},

            If[((meuEstadoGoverno
==1)&&(MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos <7))&&(
MatrizEducacaoQuantidadePessoasFormadasCalculos>400),novoEstado=7,

             If[((meuEstadoGoverno
==1)&&(MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos <5))&&(
MatrizEducacaoQuantidadePessoasFormadasCalculos>600),novoEstado=5,

              If[((meuEstadoGoverno ==
0)&&(MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos>5))&&(
MatrizEducacaoQuantidadePessoasFormadasCalculos<600),novoEstado=7,

               If[((meuEstadoGoverno ==
0)&&(MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos>7))&&(
MatrizEducacaoQuantidadePessoasFormadasCalculos<400),novoEstado=8,

                ];];];];

            Return[novoEstado];]
```

```
(*Funcao que atualiza todos os elementos da matriz de Estados: Empresas*)

AtualizarMatrizEstadosInovacao[matrizEstadosInovacao_,matrizEstadosEmpresa_,
matrizEstadosEducacao_, matrizEstadosGoverno_,
matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w = matrizLargura, h =
matrizAltura },

        For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

            For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                matrizEstadosInovacao[passoX,passoY] =
DefinirInovacaoProximoEstado[matrizEstadosEmpresa[passoX,passoY],


matrizEstadosEducacao[passoX,passoY],


matrizEstadosGoverno[passoX,passoY]

                                                                    ];

            ]

        ]

    ]

(*Funcao que atribui novos valores na matriz Vizinhos a partir da matriz de Estados
*)

AtualizarMatrizQuantidadeVizinhos[matrizEstados_,matrizQuantidadeVizinhos_,
matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w = matrizLargura, h =
matrizAltura },

        For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

            For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                matrizQuantidadeVizinhos[passoX,passoY] =
ContarNumeroVizinhos[passoX, passoY,matrizEstados,w,h ]

            ]

        ]

    ]
```

```
(*Funcao que atribui novos valores na matriz Dados a partir da matriz de Buffer *)

AtualizarMatrizDadosDeBuffer[matrizDados_,matrizBuffer_,
matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w = matrizLargura, h =
matrizAltura },

        For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

            For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                matrizDados[passoX,passoY] = matrizBuffer[passoX, passoY
]

            ]

        ]

    ]

(*Funcao que atualiza todos os elementos da matriz de Estados: Empresas*)

AtualizarMatrizEstadosEmpresas[matrizEstadosEmpresas_,matrizQuantidadeVizinh
os_,matrizEmpresasConcorrencia_,
matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w = matrizLargura, h =
matrizAltura },

        For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

            For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                matrizEstadosEmpresas[passoX,passoY] =
DefinirEmpresasProximoEstado[matrizEstadosEmpresas[passoX,passoY],


matrizQuantidadeVizinhos[passoX,passoY],


CalcularMediaEmpresasConcorrencia[passoX,passoY,matrizEmpresasConcorrencia,
w,h] ];

            ]

        ]

    ]

(*Funcao que atualiza todos os elementos da matrizBuffer: EmpresasConcorrencia*)

AtualizarMatrizBufferConcorrencia[matrizEmpresasConcorrenciaBuffer_, matriz1_,
matriz2_, matriz3_, matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w =
matrizLargura, h =  matrizAltura },
```

```
                For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

                    For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                        matrizEmpresasConcorrenciaBuffer[passoX,passoY] =
DefinirConcorrenciaBufferProximoEstado[matrizEmpresasConcorrenciaBuffer[passoX,pass
oY],


        matriz1[passoX,passoY],


        matriz2[passoX,passoY],


        matriz3[passoX,passoY]

                                                                                ];

                    ]

                ]

            ]

        (*Funcao que atualiza todos os elementos da matriz: Educacao*)

        AtualizarMatrizEstadosEducacao[matrizEstadosEducacao_,matrizQuantidadeVizinh
os_,matrizPessoasFormadas_,
matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w = matrizLargura, h =
matrizAltura },

                For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

                    For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                        matrizEstadosEducacao[passoX,passoY] =
DefinirEducacaoProximoEstado[matrizEstadosEducacao[passoX,passoY],


        matrizQuantidadeVizinhos[passoX,passoY],


        CalcularMediaQuantidadePessoasFormadas[passoX,passoY,matrizPessoasFormadas,
w,h] ];

                    ]

                ]

            ]
```

```
(*Funcao que atualiza todos os elementos da matrizBuffer: PessoasFormadas*)

AtualizarMatrizBufferPessoasFormadas[matrizPessoasFormadasBuffer_, matriz1_,
matriz2_, matriz3_, matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w =
matrizLargura, h =  matrizAltura },

        For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

            For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                matrizPessoasFormadasBuffer[passoX,passoY] =
DefinirPessoasFormadasBufferProximoEstado[matrizPessoasFormadasBuffer[passoX,passo
Y],


matriz1[passoX,passoY],


matriz2[passoX,passoY],


matriz3[passoX,passoY]

                                                                        ];

            ]

        ]

 ]

(*Funcao que atualiza todos os elementos da matriz de Estados: Governo*)

AtualizarMatrizEstadosGoverno[matrizEstadosGoverno_,matrizQuantidadeVizinhos
_,matrizFomentoInovacao_,
matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w = matrizLargura, h =
matrizAltura },

        For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

            For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                matrizEstadosGoverno[passoX,passoY] =
DefinirEducacaoProximoEstado[matrizEstadosGoverno[passoX,passoY],


matrizQuantidadeVizinhos[passoX,passoY],


CalcularMediaGovernoProgramasFomentoInovacao[passoX,passoY,matrizFomentoI
novacao,w,h] ];
```

```
                ]

            ]

        ]

    (*Funcao que atualiza todos os elementos da matriz de Estados:
FomentoInovacaoBuffer*)

    AtualizarMatrizBufferFomentoInovacao[matrizFomentoInovacaoBuffer_, matriz1_,
matriz2_, matriz3_, matrizLargura_,matrizAltura_]:=Module[{passoX=1,passoY=1, w =
matrizLargura, h =  matrizAltura },

            For[passoX=1, passoX ≤ matrizLargura, passoX=passoX+1,

                For[passoY=1, passoY ≤ matrizAltura, passoY=passoY+1,

                    matrizFomentoInovacaoBuffer[passoX,passoY] =
DefinirFomentoInovacaoBufferProximoEstado[matrizFomentoInovacaoBuffer[passoX,pass
oY],


    matriz1[passoX,passoY],


    matriz2[passoX,passoY],


    matriz3[passoX,passoY], ];

                ]

            ]

        ]

    (*INICIO DO PROCESSAMENTO DO AUTOMATO CELULAR*)

    InicializarMatrizQuantidadeVizinhos[MatrizInovacaoQuantidadeVizinhosCalculos,
largura, altura]

    InicializarMatrizQuantidadeVizinhos[MatrizEmpresasQuantidadeVizinhosCalculos,
largura, altura]

    InicializarMatrizQuantidadeVizinhos[MatrizEducacaoQuantidadeVizinhosCalculos,
largura, altura]

    InicializarMatrizQuantidadeVizinhos[MatrizGovernoQuantidadeVizinhosCalculos,
largura, altura]

    InicializarMatrizEstados[MatrizInovacaoEstadosCalculos,largura, altura]
```

InicializarMatrizEstados[MatrizEmpresasEstadosCalculos,largura, altura]

InicializarMatrizEstados[MatrizEducacaoEstadosCalculos,largura, altura]

InicializarMatrizEstados[MatrizGovernoEstadosCalculos,largura, altura]

InicializarMatrizEmpresasConcorrencia[MatrizEmpresasConcorrenciaCalculos,largura,altura]

InicializarMatrizEmpresasConcorrencia[MatrizEmpresasConcorrenciaBufferCalculos,largura,altura]

InicializarMatrizEducacaoQuantidadePessoasFormadas[MatrizEducacaoQuantidadePessoasFormadasCalculos,largura,altura]

InicializarMatrizEducacaoQuantidadePessoasFormadas[MatrizEducacaoQuantidadePessoasFormadasBufferCalculos,largura,altura]

InicializarMatrizGovernoQuantidadeProgramasFomentoInovacao[MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos,largura,altura]

InicializarMatrizGovernoQuantidadeProgramasFomentoInovacao[MatrizGovernoQuantidadeProgramasFomentoInovacaoBufferCalculos,largura,altura]

AtualizarMatrizQuantidadeVizinhos[MatrizEmpresasEstadosCalculos,MatrizEmpresasQuantidadeVizinhosCalculos, largura, altura]

AtualizarMatrizQuantidadeVizinhos[MatrizEducacaoEstadosCalculos,MatrizEducacaoQuantidadeVizinhosCalculos, largura, altura]

AtualizarMatrizQuantidadeVizinhos[MatrizGovernoEstadosCalculos,MatrizGovernoQuantidadeVizinhosCalculos, largura, altura]

AtualizarMatrizEstadosEmpresas[MatrizEmpresasEstadosCalculos,MatrizEmpresasQuantidadeVizinhosCalculos,

MatrizEmpresasConcorrenciaCalculos, largura, altura]

AtualizarMatrizEstadosEducacao[MatrizEducacaoEstadosCalculos,MatrizEducacaoQuantidadeVizinhosCalculos,

MatrizEducacaoQuantidadePessoasFormadasCalculos, largura, altura]

AtualizarMatrizEstadosGoverno[MatrizGovernoEstadosCalculos,MatrizGovernoQuantidadeVizinhosCalculos,

MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos, largura, altura]

```
AtualizarMatrizEstadosInovacao[MatrizInovacaoEstadosCalculos,MatrizEmpresasEstadosCalculos,MatrizEducacaoEstadosCalculos,MatrizGovernoEstadosCalculos, largura, altura]

AtualizarMatrizBufferConcorrencia[MatrizEmpresasConcorrenciaBufferCalculos,MatrizEmpresasConcorrenciaCalculos,MatrizEmpresasQuantidadeVizinhosCalculos,MatrizEducacaoQuantidadePessoasFormadasCalculos, largura, altura]

AtualizarMatrizBufferPessoasFormadas[MatrizEducacaoQuantidadePessoasFormadasBufferCalculos,MatrizEducacaoQuantidadePessoasFormadasCalculos,MatrizEducacaoQuantidadeVizinhosCalculos,MatrizEmpresasConcorrenciaCalculos, largura, altura]

AtualizarMatrizBufferFomentoInovacao[MatrizGovernoQuantidadeProgramasFomentoInovacaoBufferCalculos,MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos,MatrizGovernoQuantidadeVizinhosCalculos,MatrizEducacaoQuantidadePessoasFormadasCalculos, largura, altura]

AtualizarMatrizDadosDeBuffer[MatrizEmpresasConcorrenciaCalculos,MatrizEmpresasConcorrenciaBufferCalculos, largura, altura]

AtualizarMatrizDadosDeBuffer[MatrizEducacaoQuantidadePessoasFormadasCalculos,MatrizEducacaoQuantidadePessoasFormadasBufferCalculos, largura, altura]

AtualizarMatrizDadosDeBuffer[MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos,MatrizGovernoQuantidadeProgramasFomentoInovacaoBufferCalculos, largura, altura]

(*DEFINE-SE UMA COR PARA CADA NIVEL 3D*)

DefinirCorNivelJuncao[nivel_]:=Module[{cor={0.0,0.0,0.0}},

        If[(nivel == 1) ,cor={0.0,0.0,0.9},

                If[(nivel == 3) ,cor={0.0,0.9,0.0},

                        If[(nivel == 5) ,cor={0.9,0.0,0.0},

                                If[(nivel == 7) ,cor={0.4,0.0,0.4};,

                                        If[(nivel == 9) ,cor={0.0,0.9,0.6};,

                                                cor= {0.0,0.0,0.0}

                                        ];

                                ];

                        ];

                ];

        ];
```

```
            Return[RGBColor[cor]]

        ]


        (*OBTEM-SE UMA CELULA ESPECIFICA DE UM NIVEL DESEJADO*)

        ObterCelulaNivelJuncao[xCell_, yCell_,nivel_]:=Module[{estado=0},

            If[(nivel == 1) ,estado=MatrizEmpresasEstadosCalculos[xCell,yCell],(*azul*)

                If[(nivel == 3)
,estado=MatrizEducacaoEstadosCalculos[xCell,yCell],(*verde*)

                    If[(nivel == 5)
,estado=MatrizGovernoEstadosCalculos[xCell,yCell],(*vermelho*)

                        If[(nivel == 7)
,estado=MatrizInovacaoEstadosCalculos[xCell,yCell];,(*roxo*)

                            (*If[(nivel == 9) ,estado=0;,nivel extra que não
é mostrado - variavel niveis definida como 4*)

                                estado= 0

                            (*];*)

                        ];

                ];

            ];

            Return[estado]

        ]


        ProcessoGeralJuncao[interacao_, quantidadeNiveis_]:=Module[{passo = interacao},

            If[(passo > 1),

AtualizarMatrizQuantidadeVizinhos[MatrizEmpresasEstadosCalculos,MatrizEmpresasQuan
tidadeVizinhosCalculos, largura, altura]
```

AtualizarMatrizQuantidadeVizinhos[MatrizEducacaoEstadosCalculos,MatrizEducacaoQuantidadeVizinhosCalculos, largura, altura]

AtualizarMatrizQuantidadeVizinhos[MatrizGovernoEstadosCalculos,MatrizGovernoQuantidadeVizinhosCalculos, largura, altura]

AtualizarMatrizEstadosEmpresas[MatrizEmpresasEstadosCalculos,MatrizEmpresasQuantidadeVizinhosCalculos,

MatrizEmpresasConcorrenciaCalculos, largura, altura]

AtualizarMatrizEstadosEducacao[MatrizEducacaoEstadosCalculos,MatrizEducacaoQuantidadeVizinhosCalculos,

MatrizEducacaoQuantidadePessoasFormadasCalculos, largura, altura]

AtualizarMatrizEstadosGoverno[MatrizGovernoEstadosCalculos,MatrizGovernoQuantidadeVizinhosCalculos,

MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos, largura, altura]

AtualizarMatrizEstadosInovacao[MatrizInovacaoEstadosCalculos,MatrizEmpresasEstadosCalculos,MatrizEducacaoEstadosCalculos,MatrizGovernoEstadosCalculos, largura, altura]

AtualizarMatrizBufferConcorrencia[MatrizEmpresasConcorrenciaBufferCalculos,MatrizEmpresasConcorrenciaCalculos,MatrizEmpresasQuantidadeVizinhosCalculos,MatrizEducacaoQuantidadePessoasFormadasCalculos, largura, altura]

AtualizarMatrizBufferPessoasFormadas[MatrizEducacaoQuantidadePessoasFormadasBufferCalculos,MatrizEducacaoQuantidadePessoasFormadasCalculos,
MatrizEducacaoQuantidadeVizinhosCalculos,MatrizEmpresasConcorrenciaCalculos,
largura, altura]

AtualizarMatrizBufferFomentoInovacao[MatrizGovernoQuantidadeProgramasFomentoInovacaoBufferCalculos,MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos,MatrizGovernoQuantidadeVizinhosCalculos,MatrizEducacaoQuantidadePessoasFormadasCalculos, largura, altura]

AtualizarMatrizDadosDeBuffer[MatrizEmpresasConcorrenciaCalculos,MatrizEmpresasConcorrenciaBufferCalculos, largura, altura]

AtualizarMatrizDadosDeBuffer[MatrizEducacaoQuantidadePessoasFormadasCalculos,MatrizEducacaoQuantidadePessoasFormadasBufferCalculos, largura, altura]

AtualizarMatrizDadosDeBuffer[MatrizGovernoQuantidadeProgramasFomentoInovacaoCalculos,MatrizGovernoQuantidadeProgramasFomentoInovacaoBufferCalculos, largura, altura]

,(*separa a inicializacao e o processamento - quando passo e maior que 1 *)

InicializarMatrizQuantidadeVizinhos[MatrizInovacaoQuantidadeVizinhosCalculos, largura, altura]

InicializarMatrizQuantidadeVizinhos[MatrizEmpresasQuantidadeVizinhosCalculos, largura, altura]

InicializarMatrizQuantidadeVizinhos[MatrizEducacaoQuantidadeVizinhosCalculos, largura, altura]

InicializarMatrizQuantidadeVizinhos[MatrizGovernoQuantidadeVizinhosCalculos, largura, altura]

InicializarMatrizEstados[MatrizInovacaoEstadosCalculos,largura, altura]

InicializarMatrizEstados[MatrizEmpresasEstadosCalculos,largura, altura]

InicializarMatrizEstados[MatrizEducacaoEstadosCalculos,largura, altura]

InicializarMatrizEstados[MatrizGovernoEstadosCalculos,largura, altura]

InicializarMatrizEmpresasConcorrencia[MatrizEmpresasConcorrenciaCalculos,largura,altura]

InicializarMatrizEmpresasConcorrencia[MatrizEmpresasConcorrenciaBufferCalculos,largura,altura]

```
InicializarMatrizEducacaoQuantidadePessoasFormadas[MatrizEducacaoQuantidade
PessoasFormadasCalculos,largura,altura]

InicializarMatrizEducacaoQuantidadePessoasFormadas[MatrizEducacaoQuantidade
PessoasFormadasBufferCalculos,largura,altura]

InicializarMatrizGovernoQuantidadeProgramasFomentoInovacao[MatrizGovernoQu
antidadeProgramasFomentoInovacaoCalculos,largura,altura]

InicializarMatrizGovernoQuantidadeProgramasFomentoInovacao[MatrizGovernoQu
antidadeProgramasFomentoInovacaoBufferCalculos,largura,altura]

        ];


  Return[Show[Graphics3D[Table[

                                        {DefinirCorNivelJuncao[nivel],

 Opacity[ObterCelulaNivelJuncao[(xpos+1)/2,(ypos+1)/2,nivel]],

                                      Cuboid[ {xpos,ypos,nivel}]},

                                          {xpos,1,2*largura,2},

                                          {ypos,1,2*altura,2},


 {nivel,1,2*quantidadeNiveis,2}]],

                 Lighting→Automatic,Boxed→False]

        ]

  ]

 (* SIMULA TUDO COM CORES EM 3D*)

 Manipulate[ProcessoGeralJuncao[a,niveis],{a,1,100,1},FrameLabel
→{"","","Modelagem Completa",""},LabelStyle→{Blue,Italic,12,FontFamily→"Helvetica"}]
```