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A FEW AND FAR VERGED CLASSIFICATION IN CELLULAR AUTOMATA

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Abstract

Due to the lively temperament of the cellular automata, there is always a possible emergence of anomalies in its behavioral aspects. Not much hand on overlapping state, which crop up as the classification of cellular automata has been through. In this paper, a few of the unexpected arises on the basis of classification of class has been discussed. A mathematical model has been proposed for analyzing an overlap that comes out to be a far of the dynamical behavior of the cellular automata. The proposed model aims to analyze the overlap and provide a dynamic constraint-based solution for the study of dynamical systems. The fallouts can be protracted to trellis automata. The paper deals with virtual life of modern man Social Networks as complex system application. This Millennial narcissism being changed a universal living also tends to change by itself from its nature. A few years ago, social networking was the epicenter of the known earth. “Social” served as semantic pixie dust that mystically malformed any boring long-standing thing into something apropos. What's happening is that social networking is being succeeded by three things such as messaging, online distractions including YouTube, games, virtual tracking articles, podcast etc. and social media. Our proposed mathematical model studies the dynamic behaviour of the various social networks on a business perception, where social networks continuously changing into an eye-catching one rather than what it was truly.

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1. Introduction

Right from the evolution of living beings to the advancements of modern world machines, the question of how confronted the scientists. Several studies and theories failed to provide convincing answers to the questioning minds. Mathematical model was a boon to scientists and it proved to be a powerful tool in under-standing a system. From natural sciences to engineering, the ap-plication of mathematical modeling was ample to understand and observe the behavior of a system, its components, the effects of change, its prediction and so on. Among the various mathematical modeling techniques, the utilization of automata for modeling system was capable of representing several aspects of a system under study. The term cellular automata refer to the popular mathematical modeling technique which has its roots to the early 1950s. The idea behind the evolution of cellular automata was inspired by the concept of self replicating machines whose behavior was quite challenging to understand. Unlike the various classes of automata, the cellular automata aims to model a computational system with the help of a number of discrete elements called cells. The collection of such homogeneous cells forms an entire system. Change and evolution is the mantra behind the success of every business. The rapid growth of technology has influenced the business and their profit making to a greater extent by having an impact on the customer demands. It is not only about the technology but also the competition among the peer business that contributes to its success and survival. Right from manufacturing industry to software industry, the evolution over time has been drastic. Understanding the behavioral patterns of such changes in business will directly contribute to its growth. Business in the current scenario has a very high level of customer interaction. The enabler of such interactions is through the most popular Social Networks. The social networks as such as well as its depend-ant business that exist today demand the understanding of the behavioral patterns of customers in social networks which directly contribute to its success in business. Social networks are not only an enabler for business but have become a business by itself. Hence it is evolving by itself at a rapid pace. Several factors contribute to the growth and evolution of social networks. It needs to upgrade itself to meet the growing customer demands. Customer demands are not just influenced by the role of technology as such but also the influence from its peer competitors. For example, the most popular Social networking application Facebook started off as a platform to share the views and updates of its users and has now transformed as a powerful service provider. Its success is not just because of the features it keeps adding but also upgrading the features with respect to time as well as observing the behavioral pattern of its users. In this scenario, the state (success) of the social networking is to be observed based on its current state, the change in the demands of the customers, the upgradation in technology, the competition from peer social networking applications etc. Hence in order to understand the behavior of the business, various perspectives are to be considered. Mathematical modeling for such systems are quite complicated and is not capable of considering all the factors. Cellular automata are the most appropriate mathematical technique for modeling such business scenario. Though cellular automata are powerful in terms of modeling the behavior of business in the current scenario, it is not capable of modeling business with respect to varying features that contribute to the survival of business with respect to varying time frames. In this paper the overlapping class IV based behavioral pattern is to be sorted based on a feature-based state transition modeling of elementary cellular automata. The proposed feature-based state transition model for cellular automata is applied to business namely the trending social network for observing the behavioral changes in business.

2. Theoretical Background

The evolution of cellular automata was inspired by the self replicating or self evolving machines which was a research perspective of John Van Neumann. In [7] Stephen Wolfram described how cellular automata can be used to model complex systems. The system was developed to model natural system which includes snowflakes to mollusc shells. The application of trellis automata was further extended in the works of [1], [2] and [4]. The detailed description of cellular automata, its applications and research directions were provided in [8]. The evolution of cellular automata paved way for the research based on the behavioural classes of cellular automata which was elaborated in [3]. Though the applications of cellular automata were vast and it revolved around various areas ranging from cryptography [9] to medicine [10], very few works focus on the application of cellular automata to model business scenarios. The study in [4] and [5] provides a motivation to apply cellular automata to model business scenario. Cellular automata are a collection of homogeneous population of cells represented in a lattice forms a system and each of the cells in the system has its own states. The state of the cells in the system is based on the states of its neigh-boring cells. The changes in the state of every individual cell in the system thus illustrate the change in the system as a whole. This kind of modeling enabled to understand every single detail of the system that contributes to the change in the behavior of the system as a whole with respect to a given time. As the time varies, the cellular automata evolve with its generations. The elementary cellular automaton is the simplest class and is one dimensional. An elementary cellular automaton has possible two values for each cell and these values are decided based on the state of the neighboring cells. The following figure illustrates an elementary cellular automaton which has n states and each state is represented by $S_0^t \ldots S_n^t$. It can be observed that the state S^{ti} of a system depends on the previous state S_{i-1}^t and S_{i+1}^t of the system. This automaton has its states corresponding to time t and hence superscripted with the symbol t and when the time changes from t to $t+1$ (i.e. evolves to the next generation), the corresponding states are obtained as a result of the previous generation states and that of its neighboring states and is represented in the following equation

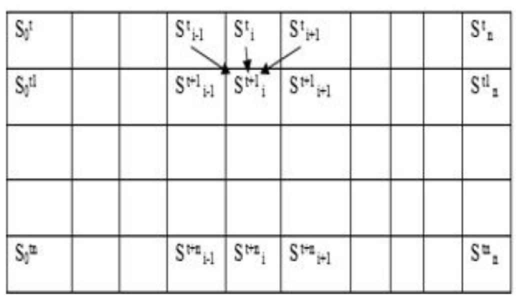

Figure 1. Elementary Cellular Automaton.

$$S_i^{t+1} = \phi[S_i^t, S_i^t, S_{i+1}^t].$$

The state of cells in elementary cellular automata is represented with the help of rules and [6] indicates the rule set. Among the various rules, there are rules which yield similar behavioral patterns. Such rules are grouped and are categorized into four classes namely cellular automata evolving to homogeneous state (Class I), cellular automata evolving periodically (Class II), cellular automata evolving chaotically (Class III) and cellular automata evolving to complex dynamics. (Class IV). If the evolution is dominated by a unique state of its alphabet (that of state 0 or 1) for any random initial condition, then it belongs to Class I. If the evolution is dominated by blocks of cells which are periodically repeated for any random initial condition, then it belongs to Class II. If for a long time and for any random initial condition, the evolution is dominated by sets of cells without any defined pattern, then it belongs to Class III. If the evolution is dominated by non-trivial structures emerging and traveling along the evolution space where uniform, periodic, or chaotic regions can coexist with these structures, then it belongs to Class IV. In class IV, the pattern cannot be defined and hence it is termed as complex. The co existence or overlapping of class that exist in class IV is an issue yet to be explored. In the current scenario, the behavior of every modern system has overlapping pattern. In such cases, further understanding of such behavioral patterns become essential.

Figure 2. Behavioral Class I in cellular automaton.

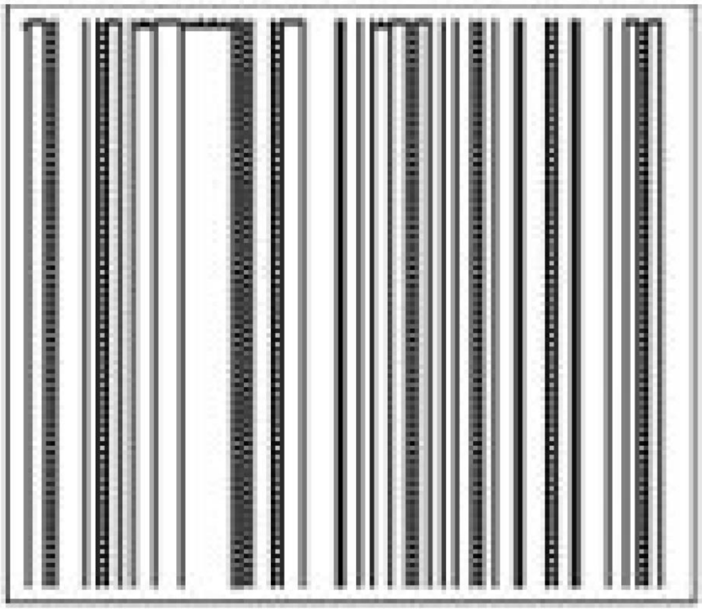

Figure 3. Behavioral Class II in cellular automaton.

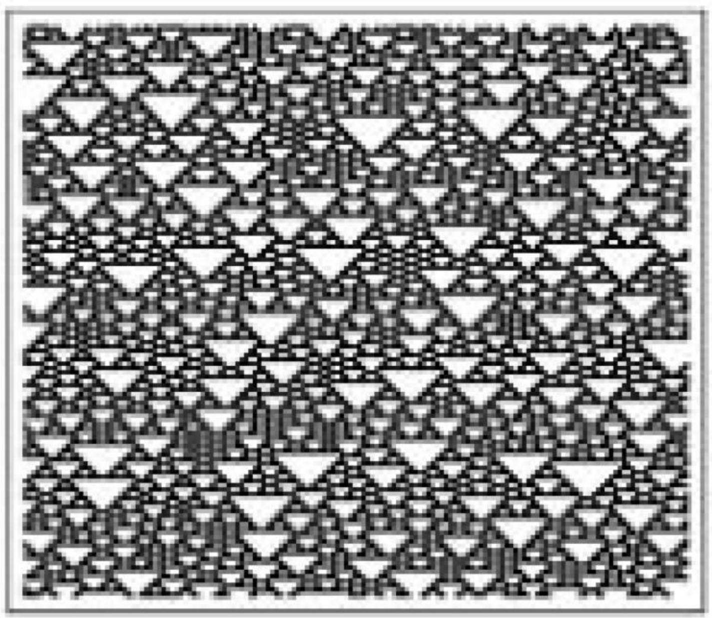

Figure 4. Behavioural Class III in cellular automaton.

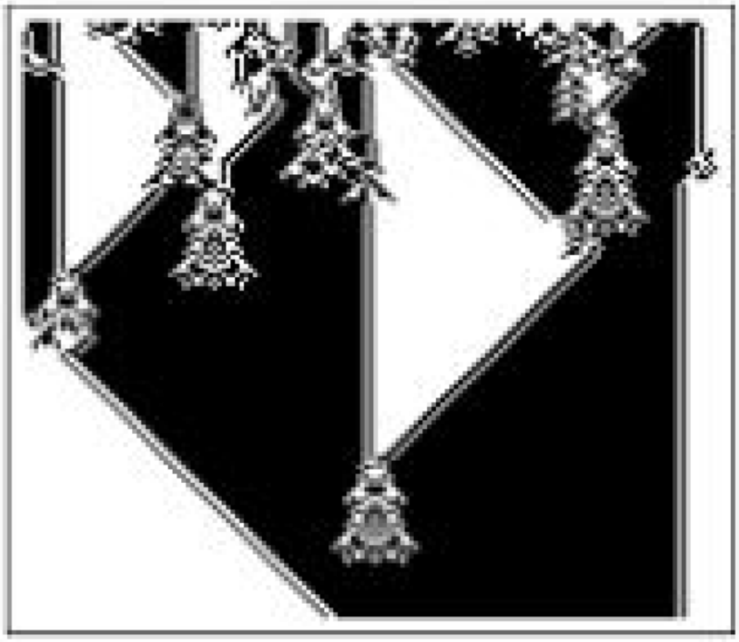

Figure 5. Behavioural Class IV in cellular automaton.

3. Proposed System

The issue in sorting the co existence of various classes in Class IV in cellular automaton aims in better understanding the state of system. This requires refining the state representation with additional information apart from the current state of the system with respect to time. A system apart from having a state for a particular time instance has also factors that make the system to reach that particular state. For example, consider the switch of a light bulb, it has two distinct states on and off. The switch can be on/ off at a particular instance of time, but the state change of the switch occurs only when the light bulb has to switched on when dark/ in case of lack of visibility. In modeling such a scenario, two parameters were considered namely the state of that system and the time at which the state changes. But the need for the state of the system to change is completely neglected. In modeling complex systems, it is not sufficient to only consider the state of the system with respect to time but also the factors which contribute to the change in system. If such factors are to be incorporated for a particular instance of time, then better understanding of the behavioral pattern can be achieved and such overlapping or co existence among states for complex dynamics in Class IV can be eliminated. Consider the states of the elementary cellular automaton for a particular instance of time t with the factors contributing to state change fk as $S_0^{f(t, fk)} \ldots S_n^{f(t, fk)}$. Where fk is the factors contributing the state change of the system $k = 1, 2, 3, \ldots, n.$ Here, the state of a system is computed with respect the function of features with respect to time. The features that contribute to change in the state of the system may vary based on time or the system considered. The function is determined as follows

$$f(t,\ fk) = \int_1^k t,\ \log_{10} k.$$

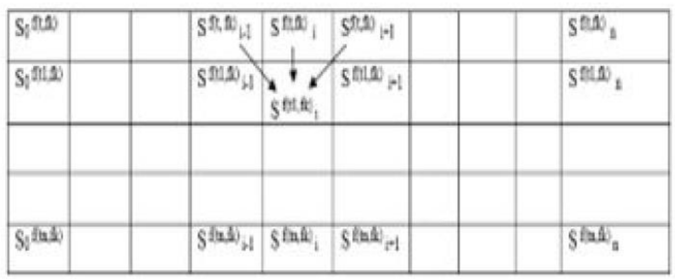

Figure 6. Modified view of elementary cellular automaton.

Here t denotes the time at which the state change for the system occurs k denotes the number of factors that contribute to the system change. For example, consider for the scenario of smartphones. There are 3 states of a mobile phone idle, off, and in use. It can be observed that the smartphones when launched was used only for calling and messaging purposes. Now the factors for using it has been scaled up for mail updates, for social networks, for editing various files etc., This has been evolved over time. The modeling of this scenario using the proposed cellular automata may be illustrated as follows. For a time $t = 1,$ the smartphone is an off state and the factors contributing to it at that particular instant may be due to the users intent or lack of battery. Here the number of factors is 2 and the time is 1.

$$S_0^{f(1,\ 2)} = \int_1^2 1 \cdot \log_{10} 2 \setminus 0.3 \sim 0.$$

Hence for time, $t = 1$, the smartphone is an on state and the factors contributing to it at that particular instant may be for calling purpose. Here the number of factors is 1 and the time is 1

$$S_0^{f(1,\,1)} = \int_1^2 1 \cdot \log_{10} 2 = 0.3 \sim 0.$$

For time $t = 1$, the smartphone is idle state and the factors contributing to it at that particular instant may be due to the users intent. Here the number of factors is 1 and the time is 1

$$S_1^{f(1,\,1)} = \int_1^1 1 \cdot \log_{10} 1 = 0.$$

For time $t = 2$, the smartphone is an on state and the factors contributing to it at that particular instant may be for calling purpose and messaging purpose. Here the number of factors is 2 and the time is 2.

$$S_2^{f(1,\,2)} = \int_1^2 1 \cdot \log_{10} 2 = 0.3 \sim 0.$$

In the similar fashion modeling may be carried out for the given smartphone scenario. In case of obtaining negative values for the states, may be approximated to the nearest negative integer value. In this case the ruleset has to be elaborated and in turn the co existence of states in the system in the complex systems can be brought down. The proposed system is simpler and efficient when compared to modeling n dimensional cellular automata. The complexity with the n dimensional cellular automata is eliminated by incorporating the factors that contribute to the state change.

When considering the more than two neighboring cells in case of the n dimensional cellular automata, the behavioral pattern will be much inuenced by the previous and possible states of the system rather than considering the factors that contribute to the cur-rent state of the system.

4. A Social Network Perspective

A virtual Community or social profiler, which theatres a major role in worlds social life, that brings all the ingredients of every individual illustration of social life in a solitary platform. Several virtual communities are available today such as Facebook, Bebo, Classmates, LinkedIn, and Path etc.

Table The pervasive social networks

Social Networks	Description
Bebo	Sharing and Networking website
Facebook	4th Populated country
Google +	A social network from Google
Path	Online path laid to travel with friends family
Pininterest	Online Picture World
Twitter	A social network pulse
Youtube	Online Video Universe

To understand the behavior of social networks it is first essential to understand the users behavior in social platform.

4.1. User Behavior in Social Networks. A user's behavior in social networks can be termed as Second Life which may be considered as 'Virtual' exhibits an inimitable behavior incomparably to the real world. When it comes to behavior analysis of Homo sapiens, there are some basic principles that which made behavior a measurable and observable. Research Question: How user behavior downs the usage of Social networks? Countable number of social networks creates a choice for any individual human to go for more than one social network and since the account creation of any social network seldom charges the user, it makes the user to set up a virtual profile in almost every social network. The competition of the peer social net-works is thus indirectly created to the social networks through the users. The following lemma makes it clear that the behavior of one social network may or may not depend on another social network.

4.2. Superposition Lemma. If $y_1(x, t)$, $y_2(x, t)$ are the solutions to the different social net-works and K_i arbitrary constants then the sum

$$y_s(x, t) = K_1 y_1(x, t) + K_2 y_2(x, t)$$

where $i = 1, 2, 3$ may be another solution.

In order to prove $y_s(x, t)$ is a prime solution, we expand $yst2$, to see if indeed it is equal to

$$C^2 * \frac{\partial y_s}{\partial x^2}.$$

Then by the definition of $y_s(x, t)$:

$$\frac{\partial y_s}{\partial t^2} = \frac{\partial}{\partial t^2}(K_1 y_1(x, t) + K_2 y_2(x, t) + \ldots).$$

By applying the Sum of Derivatives:

$$K_1 \frac{\partial^2}{\partial t^2} y_1(x, t) + K_1 \frac{\partial^2}{\partial t^2} y_2(x, t) + \ldots$$

We assumed that $y_s(x, t)$ is a solution for the given problem, hence

$$C^2 * \frac{\partial^2 y_1}{\partial x^2} = \frac{\partial^2 y_1}{\partial t^2}, \; C^2 * \frac{\partial^2 y_2}{\partial x^2} = \frac{\partial^2 y_2}{\partial t^2} + \ldots$$

If we now substitute R.H.S with L.H.S, then the equation will be of:

$$C^2 * \left(K_1 \frac{\partial^2}{\partial t^2} y_1(x, t) + K_2 \frac{\partial^2}{\partial t^2} y_2(x, t) + \ldots \right).$$

Again, by using the Sum of Derivatives, then:

$$C^2 * \frac{\partial^2}{\partial x^2}((K_1 y_1(x, t) + K_2 y_2(x, t) + \ldots).$$

By sum of the solutions assumed

$$C^2 * \frac{\partial^2}{\partial x^2} y_s(x, t).$$

Thus, the Superposition Lemma proved, which shows up the two different social networks can be overlapped each other with the same medium and shall be independent of each other too. Moreover, the above equation can be used to find the general solution of the behavior of any social network within a medium itself. The above lemma itself shows the possibility of co existence of behavior classes when modeling the above system using cellular automata.

5. Conclusion

Cellular automata, the mathematical model for representing the behavior of a system though dates back to early 1950s proves to be the most efficient means of modeling. The demand of modeling the behavior of modern systems leads to the class IV of complex dynamics in cellular automata. The complex dynamics has various classes co existing in itself which throws a challenge in understanding the behavior of modern systems. Such a complex behavior is due rapidly evolving states of the system which leads to the lack of understanding the behavioural pattern of modern complex systems.

This paper elaborates on the need to consider additional factors in modeling a system. The scenario of social network business modeling is considered to enforce the need of a cellular automata which not only requires the state of a system with respect time but also additional factors to understand the behavior of such complex system and to refine the class IV of cellular automata. The proposed system presents a factor based state transition modeled elementary cellular automata that considers factors which contributes to change of state in a system with respect to time. For a state change it is not just the time and state of the neighboring cell states but also the factors that lead to the change of the state for that instant of time. The proposed model is validated for a simple real time scenario and it proves to be simple and efficient when compared to the complicated n dimensional automata.

References

[1] E. Goles, A. Moreira and I. Rapaport, Communication complexity in number-conserving and monotone cellular automata, Theoretical Computer Science 412 (2011), 3616-3628.

[2] N. H. Margolus, Universal Cellular Automata Based on the Collisions of Soft Spheres. In: Griffeath, D., Moore, C. (eds.) New Constructions in Cellular Automata, Oxford University Press (2003), 231-260.

[3] K. Sutner, Classification of Cellular Automata Meyers, R. A. (ed.) Encyclopedia of Complexity and Systems Science 3 (2009), 755-768.

[4] S. C. Bankes, Exploratory modeling for policy analysis, Operations Research (1995), 435-449

[5] C. Wilson, A. Sala, K. P. N. Puttaswamy and B. Y. Zhao, Beyond social graphs: user interactions in online social networks and their implications, ACM Trans. Web 6 (2012), 1-31.

[6] Wolfram, Stephen, Universality and complexity in cellular automata, Physica D: Nonlinear Phenomena (1985), 1-35.

[7] Wolfram, Stephen, Cellular automata as models of complexity, Nature 311.5985 (1984), 419-424.

[8] B. Chopard and M. Droz, Cellular Automata, Springer (1998).

[9] Stephen Wolfram, Cryptography with Cellular Automata, Conference on the Theory and Application of Cryptographic Techniques, Springer, Berlin, Heidelberg, (1985).

[10] Vladimir Vezhnevets and Vadim Konouchine, Grow Cut: Interactive multi-label ND image segmentation by cellular automata, Sproc. of Graphicon, (2005)