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TRANSITIVITY MATTERS. NORMS ENFORCEMENT AND DIFFUSION USING DIFFERENT NEIGHBORHOODS IN CAs.

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Transitivity matters. Norms Enforcement and diffusion using different neighborhoods in CAs.

Bertazzi, I.[*]

ABSTRACT

The study of norms' self-enforcement and diffusion is one of the most acknowledged application of ABMs. Peer pressure, limited knowledge and communication channels are some of the most accounted elements in this kind of modelization, and for these same reasons, cellular automata models are very popular for the subject.

A very interesting model in this ambit is Centola, et al. (2005). *"The Emperor's New Clothes"*, the popular fable, is used as example of a society where stable compliance to a norm that the majority does not want to observe is made possible by the presence of a committed minority that triggers compliance cascades through peer-pressure.

This paper, starting from the original code, unfolds the concept of "cascade" phenomena. Changing the order of procedure and especially the neighborhood structure is not only a way to test results robustness; the transitivity structure of two different neighborhoods (Von Neumann and Moore neighborhood), on which the local rule is constructed, develops completely different emergent results, under similar initial conditions. Results from this work give insights on how code design strongly changes outcomes interpretation, in particular the concepts of "cascade" and "diffusion".

KEYWORDS: Cellular Automata, Norms, Diffusion, Cascades, Model Replication.

SEC 1. INTRODUCTION

This paper, starting from the original code of Centola et al. (2005), a very simple and powerful CA model of social interaction, as presented in section 2, unfolds the concept of "cascade" and "avalanche" phenomena, widely used in the field. The contribution of the present paper is the analysis of the evidences that changing the order of procedures and the neighborhood structure is not only a way to test results robustness, but it also shows that transitivity of local structure and the choice between two different kinds of neighborhoods (Von Neumann and Moore neighborhoods) matters, in other words, the possible number of cells considered in the evaluation of the transition rule of the CA develop completely different emergent results under similar initial conditions. The modifications taken into account are explained in section 3. Results from this work, as interpreted in the forth and fifth sections, give insights on how code design strongly changes outcomes interpretation, in particular the concept of "cascade". The elucidation on the model and on the work addressed in the paper follows the standards of the updated ODD Protocol, as designed by Grimm et al. (2010).

SEC 2. MOTIVATION AND THE ORIGINAL MODEL

In terms of the updated ODD Protocol, the purpose of this work lies in the area of Replication of interesting results and simulations, which is an important part of the evolution of simulation as a tool for social sciences. As pointed out by Axelrod (2003), three important stages of the research

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process for doing simulation in the social sciences have been considered more frequently: programming, or model design, results interpretation, or analysis, and the sharing computer simulations results. There is, however, another stage of the research process that is virtually never done: replication. Replication is one of the hallmarks of cumulative science. It is needed to confirm whether the results of a given simulation are reliable and robust in terms of model design. Replication can also be useful for testing the robustness of inferences and the model sensitivity to parameter calibration.

Moreover, this replication phase is very important for a kind of social simulation as widely use as CAs are. As first step, here is introduced a general definition of Cellular Automata, than the original model to be replicated is presented.

A n-dimensional CA consists of: 1. a n-dimensional grid (2-D in our case); 2. cells assume one of a finite number of possible states; 3. time advances in discrete steps; 4. cells change their states according to an update rule, the state of a cell in the next period depends upon the states of neighboring cells and itself in past period; 5. the transition rules are usually deterministic, like in this model, but also probabilistic rules are possible; 6. usually, the system is homogeneous in the sense that the set of possible states is the same for each cell and the same transition rule applies to each cell, in the present case the possible state that a cell can have depend on the cell's type; 7. the updating procedure usually consists of applying the transition rule synchronously or selecting cells randomly, which is the case for the current model.

As many scholars pointed out, for instance Batten (2000), CAs are important for social simulations because of their simplicity in designing spacial interactions, because of their flexibility in applications to social system with agents in an interactive network.

The Model described in Centola, et al. (2005), called the “Emperor Dilemma Model” is a design for a Cellular Automata model to study norms, intended as behavioral rules with no centralized enforcement mechanism, but a kind of rule that base its diffusion and stability on neighborhood peer-pressure. It is an interesting case for replication because it represents a base for a general model for unpopular, self-enforcing norms , with a simple simulation algorithm .

The name comes from Hans Christian Andersen’s fable “The Emperor's new clothes”, where there is a vast majority of people in the population that do not believe that the Emperor clothes exist, but they say and behave as if they believed it, and the entire mechanism is driven by the presence of a small portion of the population highly convinced of the “norm”, a phenomena known as “Informational Cascade” .

In this 2-dimensional grid, agents/cells have two different Belief statuses (+1/-1) and they can comply or not comply the norm, as well as enforce it or not, where the norm is supported by few fanatics and opposed by the majority .

The transition rule (the mechanism by which the cells update their statuses in terms of Compliance (C(i)) and Enforcement (E(i)), can be summarized as follows:

$$B_i = \pm 1$$

$$C_i = \begin{cases} -B_i \ldots if \dfrac{B_i}{N_i} \sum_j E_j > S_i \\ B_i \ldots otherwise \end{cases}$$

$$E_i = \begin{cases} -B_i \ldots if \left(\dfrac{B_i}{N_i} \sum_j E_j > S_i + k\right) \wedge (B_i \neq C_i) \\ B_i \ldots if\ (S_i * w_i > k) \\ 0 \ldots otherwise \end{cases}$$

Where: $w_i = \frac{1-(\frac{B_i}{N_i})\sum_j C_i}{2}$

Where B(i) represents the (given) belief over the norm; C(i) is the Compliance; E(i) the Enforcement (both dependent on the j-neighbors state of Enforcement); w(i) can be defined as the "need for enforcement", to be intended as the potion of neighbors how behave according to one's beliefs or not (so, dependent on C(j)); S(i) represents an heterogeneous variable of the "strength of conviction" to one's own belief, for fanatics this value is fixed at the maximum 1, where for the others it is uniformly distributed from zero to a certain (smaller) level; *k* is a global variable representing the cost of Enforcement, negatively affecting the adoption of this behavior, both in terms of E(i) in accordance to one's own belief or in opposition.

In terms of the Update ODD protocol, Cells structure and type positioning in the 2-D grid are defined as Entities of the model, their state variables are, of course, all the determinants of their state in terms of Belief, Compliance and Enforcement.

One important feature of this model is its lack of content in terms of the norm, leading to a very wide range of possible applications.

SEC 3. CODE TEST VERSIONS AND VARIABLES CALIBRATION

The replication process adopted in this paper explores, starting from some robustness tests, the possibility space of some independent variables that were not mentioned in the original paper. In particular, original results were focused on the effect of the number of fanatics in the population and their position in the grid, as these initial setting affected the percentage of "normal" opposer to the norm affected by the informational cascade and ending up enforcing to their neighbors a norm that they did not like in the first place. In this paper, on the other hand, the focus will be on the type of outcome that originates from one or other spacial knowledge of each cell (also called neighborhood), and on how this is affected by variables calibration.

The replication of the code started from the original code, made publicly available by the authors and suitable for NetLogo 3.* ; the process of updating of the code for newer versions of the program also included the possibility of a much faster algorithm, since the random order of cell updating of their status has previously to be imposed via looping algorithm of asking, while it is featured automatically for up-to-date Netlogo versions (Netlogo 5.1).

The next sections will describe the variable taken into account in this replication process (neighborhoods and clustering, cost variable and code versions), and it is classifiable in the ODD update Protocol both as Process overview and Design concepts, in particular the Basic Principles, the Interaction mechanism and the Stochasticity present in the model. The last part of section 3 is dedicated to the presentation of the results obtained.

Sub Sec 3.1 Environment: Neighborhood and clustering

Both the original model and this replication explore the different possibilities in the position of the small fanatic minority, which can be placed clustered or dispersed randomly in the grid.

During the first replications, there emerged intuitively a possible difference in outcomes for a particular variable of CAs, the number and the position in space of the cells that are included in the transition rule evaluation of a single cell, also called, neighborhood structure of the CA. Traditionally, two types of very popular neighborhood structure are used for 2D cellular automata, Von Neumann and Moore.

Von Neumann's neighborhood Moore's neighborhood [1]

The two structures have a formal definition for any N-dimensional CA, which can be found in Kari (2004):

> The Von Neumann neighborhood contains relative offsets $\vec{y}$ that satisfy $||\vec{y}||_1 \leqslant 1$ where
>
> $$||(y_1, y_2, \dots y_d)||_1 = |y_1| + |(y_2)| + \dots + |(y_d)|$$
>
> is the Manhattan norm. This means that cell in location $\vec{x}$ has 2d + 1 neighbors: the cell itself and the cells at locations $\vec{x} \pm \vec{e}_i$ where $\vec{e}_i = (0, \dots, 0, 1, 0, \dots 0)$ is the i-th coordinate unit vector. The Moore neighborhood contains all vectors $\vec{y} = (y_1, y_2, \dots, y_d)$ where each y_i is −1, 0 or 1, that is, all $\vec{y} \in \mathbb{Z}^d$ such that $||\vec{y}||_\infty \leqslant 1$ where
>
> $$||(y_1, y_2, \dots, y_d)||_\infty = max\{|y_1|, |y_2|, \dots, |y_d|\}$$
>
> is the max-norm.

An important differential feature of the two structures for 2D CAs is the transitivity of the neighbor relationship. As shown in the picture, Von Neumann 4-neighbor structure is not transitive in the sense that a cell's neighbors are not neighbors to each other, whereas it is the case for Moore 8-neighborhood. This feature, although mentioned in the original paper, is not object of careful inquiry in the original illustration of the results. Here this element, combined with the following illustrated tests and calibrations, reveals itself to be crucial in the deep comprehension of the dynamics of this model; this is particularly important if the social element of this simulation is taken into account, as developed in the forth section.

Sub Sec 3.2 Procedures orders

As in many applications of CAs to social simulations, the agents represented as cells in the grid of this model are designed as so-called "zero intelligence agents", to say, they to not have any learning process, no maximization function or expectation over the outcome. Their behavior is completely deterministic and depending on a certain transition rule just based on neighbors state.

This consideration raises an interesting question concerning the order of application of the three different parts that constitute the specific transition rule of this model. As previously explained, the procedures that are evaluated by each agent at every time step are:

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1 Immage from Allouche, Courbage, and Skordev (2001).

- Determination of compliance C(i) based on neighbors' enforcement values E(j).

- Determination of the need for enforcement w(i), based on neighbors' behavior in terms of C(j)

- Determination of enforcement (the message sent to neighbors for the next time-step) E(i), also based on E(j).

This is the original model's order of procedure (which I will call version 1.0); since the order of these steps is mainly arbitrary, because of the zero intelligence characteristic of the agents, the following procedure orders are also tested, as the all possible combinations of orders, leading to different patterns in the results:

Version 1.1	Version 1.2	Version 1.3	Version 1.4	Version 1.5
W(i) C(i) E(i)	W(i) E(i) C(i)	C(i) E(i) W(i)	E(i) W(i) C(i)	E(i) C(i) W(i)

Sub Sec 3.3 Cost variable calibration

The value of *k*, which is fixed by the authors of the original model 0.125, was designed for agents with eight neighbors, in the way that there is a so-called "threshold" for additional neighbor that must enforce before a false believer becomes a false enforcer as well. Formalizing this concept:

k = 0.125 s.t. In Moore Neighborhood, for i with $B_i=-1 \wedge C_i=1$ (so-called False Compliers),

$$\sum_j (neigbors\, s.t.[E_j]=-1)-\sum_j (neigbors\, s.t.[E_j]=1)>k-determined\, Treshold \Rightarrow E_i=1$$

Where the values of conviction is uniformly distributed across non-believers population with a maximum equal to 0.38; together with cost, this two variables form a cumulative uniform distribution of false enforcement thresholds across the population of disbelievers, such that, for agents with Moore Neighborhood, if two more neighbors are enforcing compliance than are enforcing deviance in every disbeliever's neighborhood ($\sum_j ([E_j]=-1)-\sum_j ([E_j]=1)>2$), then about one-third of the disbelievers will falsely enforce (False Enforcers are the cells who have $B_i=-1$ but $E_i=1$). If three more neighbors enforce compliance than deviance ($\sum_j ([E_j]=-1)-\sum_j ([E_j]=1)>3$, then about two-thirds of disbelievers will falsely enforce, and so on.

Cost *k* Also represents a "tolerance" level for "fanatics" ($B_i=1$), in the sense that, when its level are too high, there is no possibility for believers to make any enforcement because this action is too "expensive"; in fact:

$E_i=1$ for $B_i=1$ [and also $s_i=1$] i.i.f:

$s_i * w_i > k$ => $w_i > k$

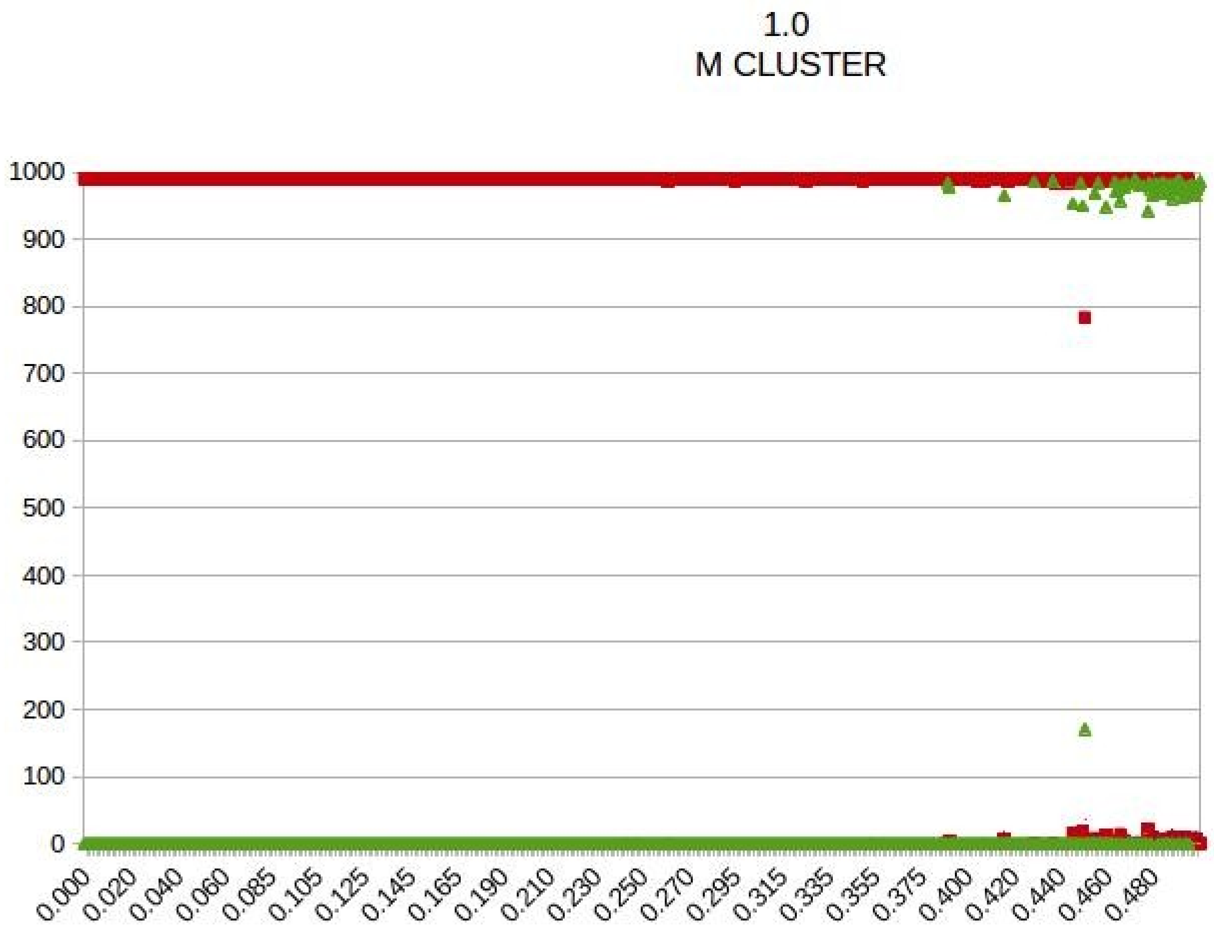
This represents the percentage of neighbors who are in accordance or not in accordance to the fanatics' believe. For example in Moore Neighborhood, a level of *k*=0. 125 represents a "tolerance" of 1 neighbor non complying for the agent to enforce (if there are two or more neighbors non complying, E_i will be 1), and so on as *k* increases.

All these considerations, and the behavior sensibility to *k* calibration, call for a careful exploration of the possibility space of cost variable.

Sub Sec 3.4 Simulation Experiments Results

The following plots represent the outcome of several run of the different simulation, each point represents a counting of different types of cells after 500 time-steps; red dots are the number of False Enforcers ($B_i = -1 \wedge E_i = 1$), where green dots are Non Compliers ($B_i = -1 \wedge C_i = -1$). In each line a different code version is represented.

First plots are regarding Moore Neighborhoods experiments (the first line of the title refers to the code version, M is for Moore and VN is for Von Neumann), than Von Neumann's follow, highlighting the deep difference in the two outcomes. The first series depicts a very specific outcome possibility space, with a 100% False Enforcers for small k levels, and two coexisting scenarios for higher k – a totality of Non Compliers or a totality of False enforcers as before.



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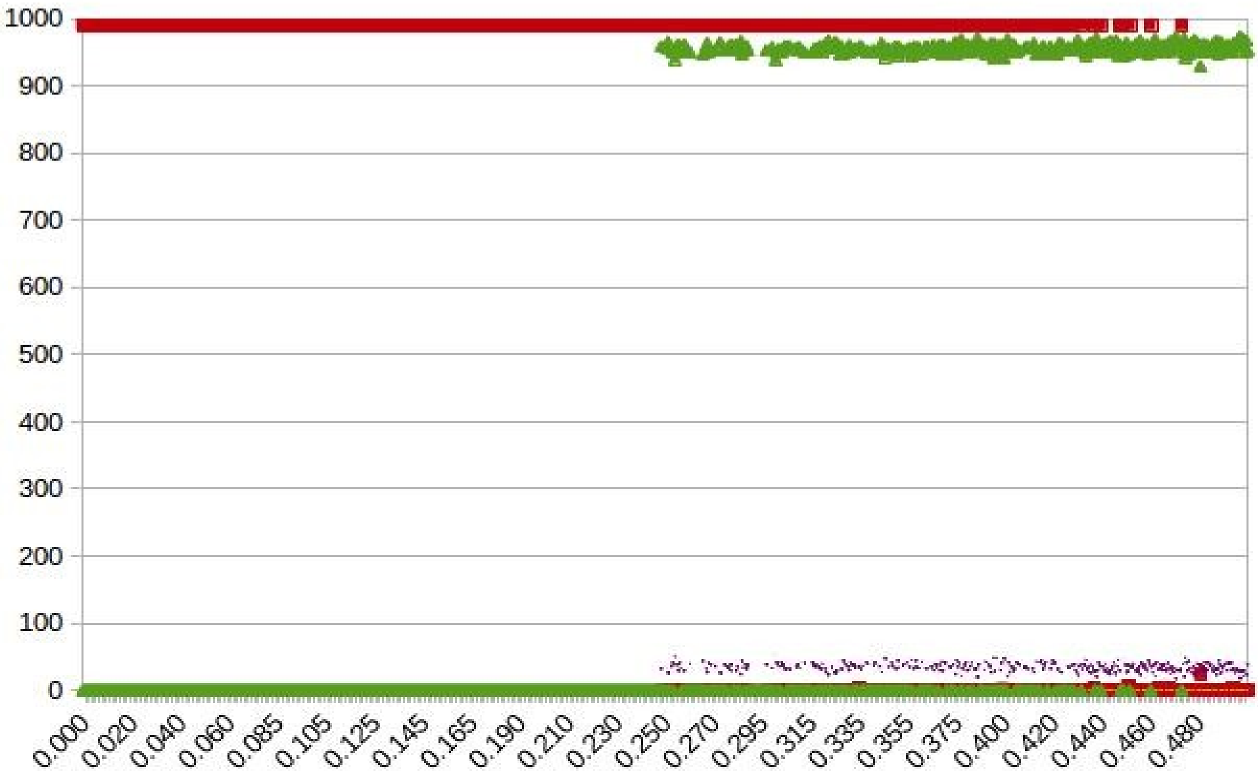

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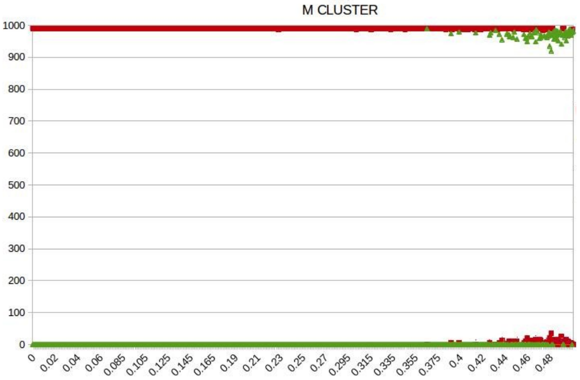

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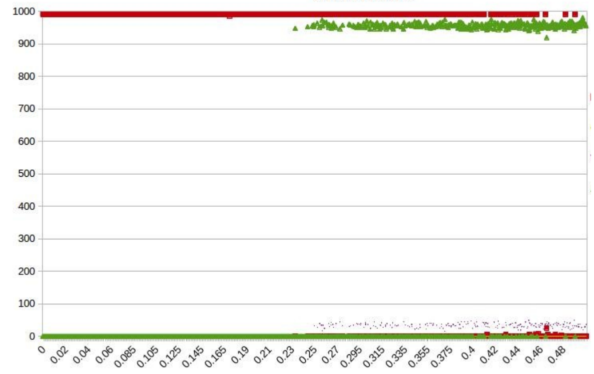

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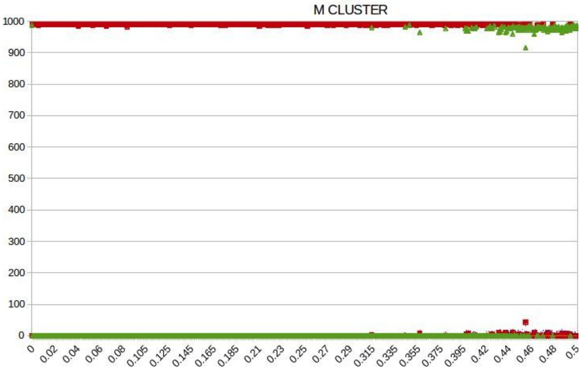

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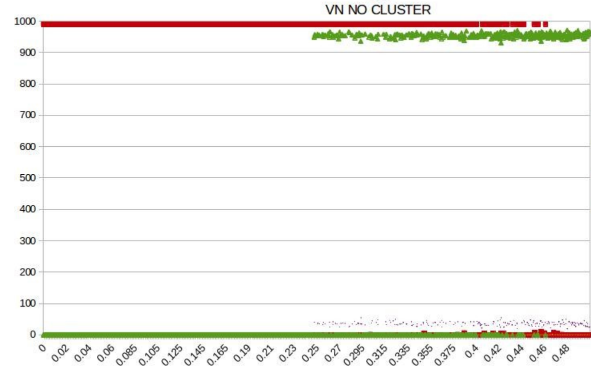

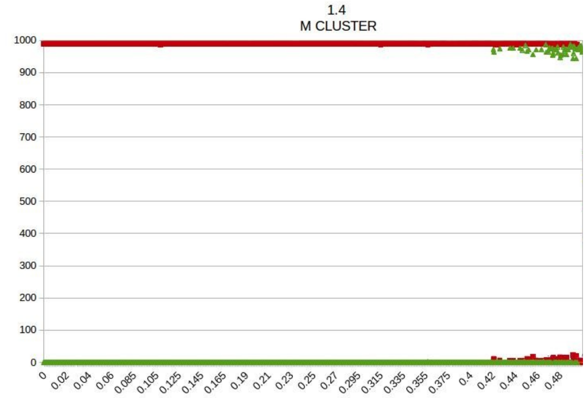

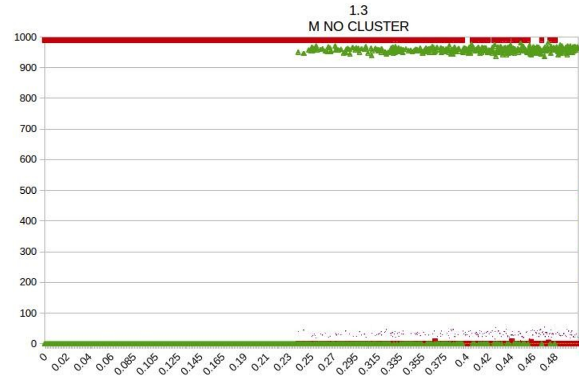

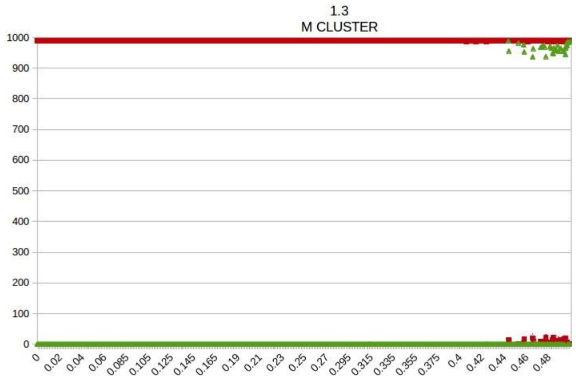

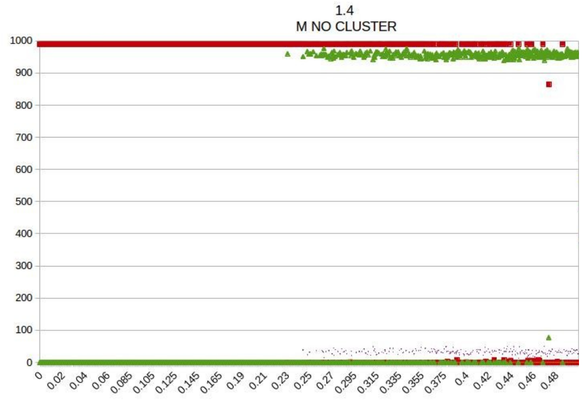

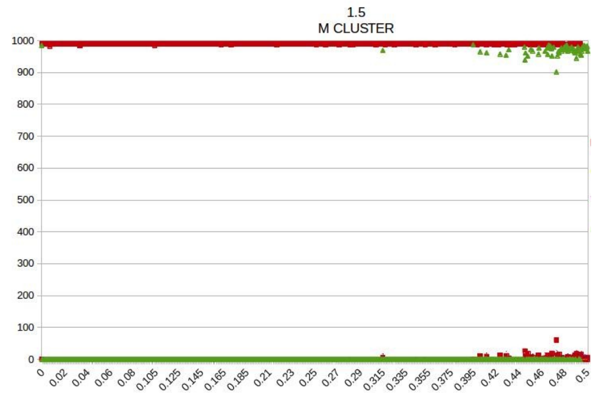

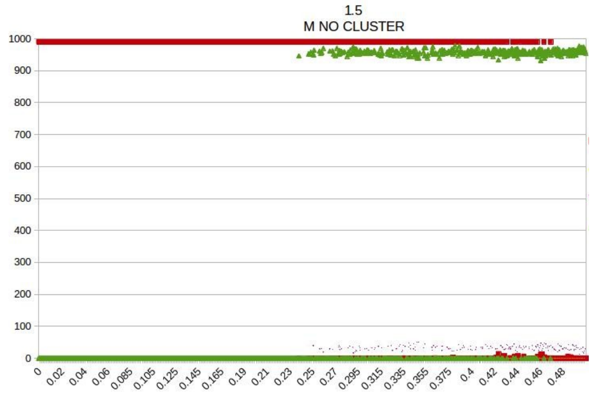

The following second series of plots is, on the contrary, based on Von Neumann, non Transitive neighborhoods. The shape and position of red and green dots (i.e. the number of False Enforcers and Non Compliers after 500 runs of each simulation) is completely different than the previous case, absolutely not unique in the possible emerging landscapes.

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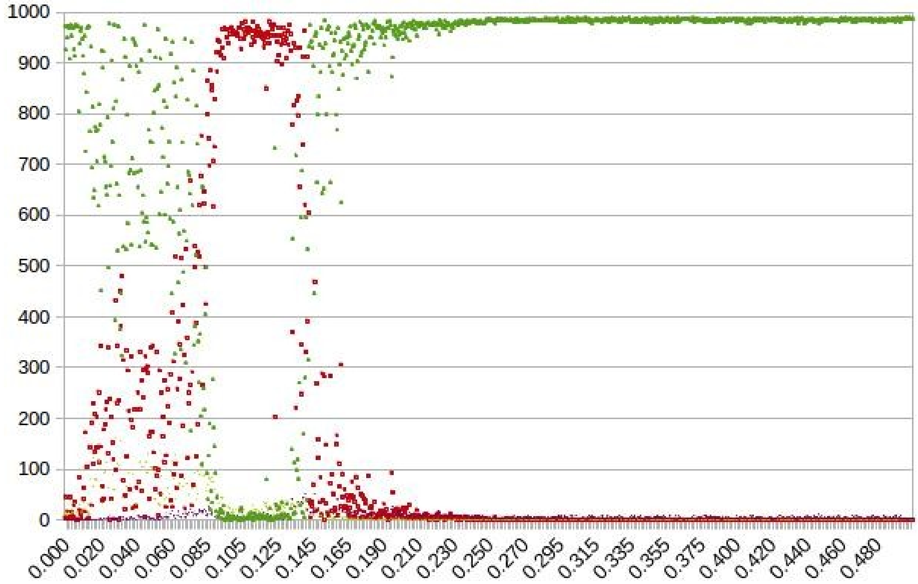

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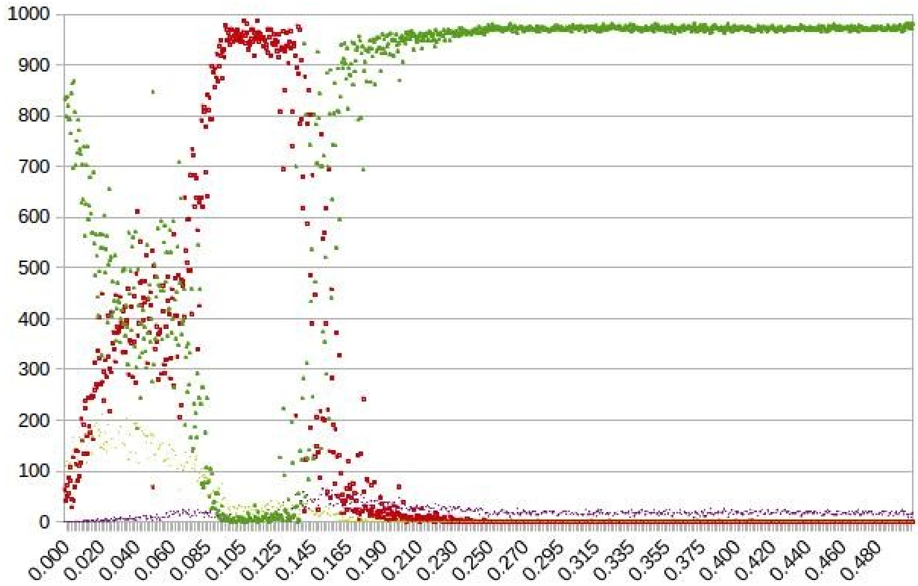

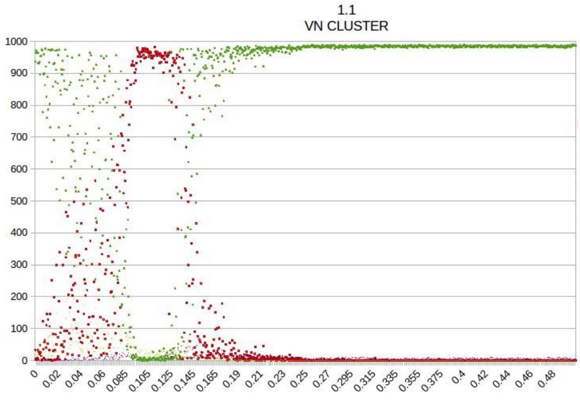
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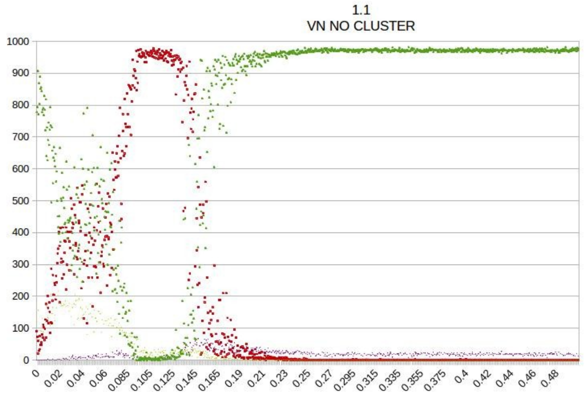
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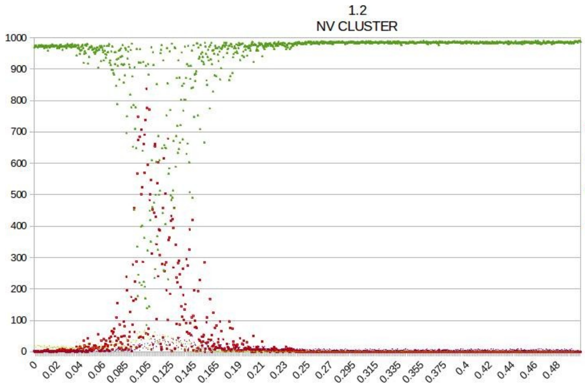
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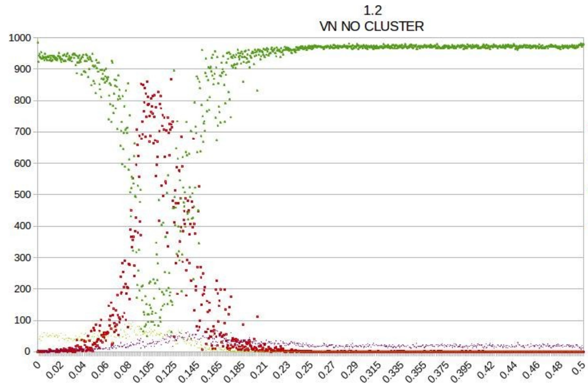
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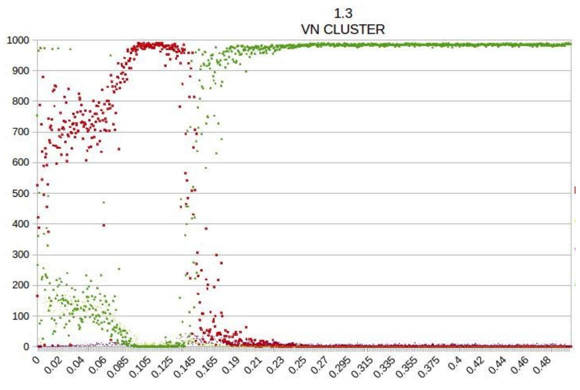
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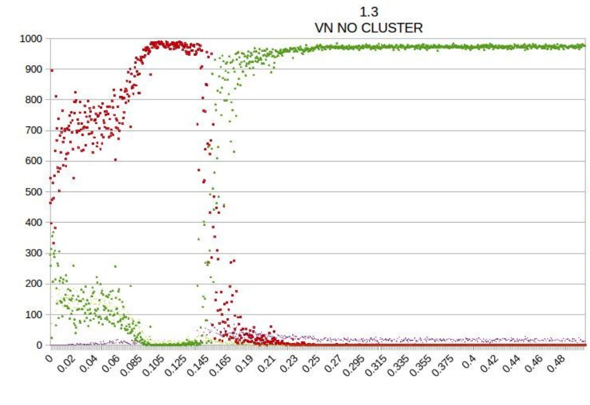
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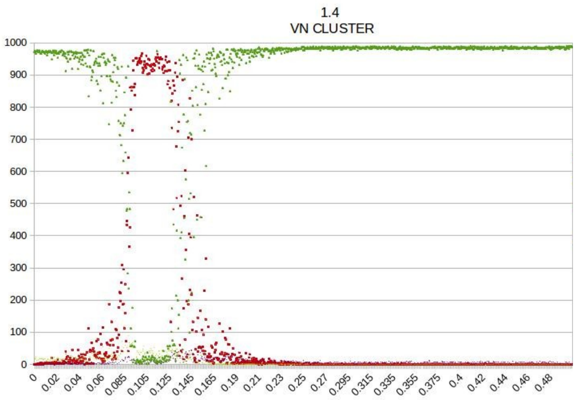
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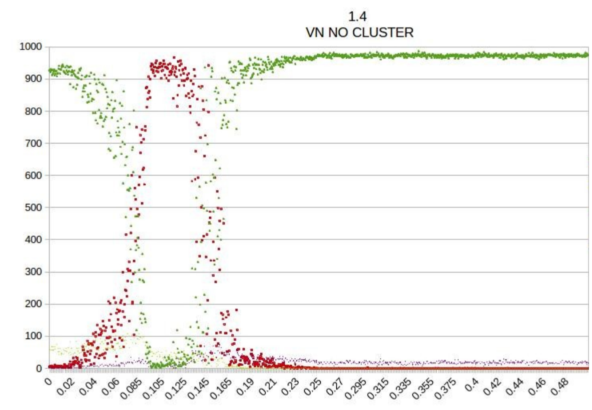
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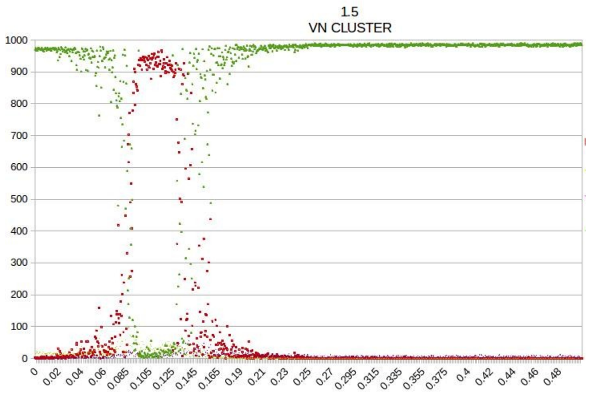

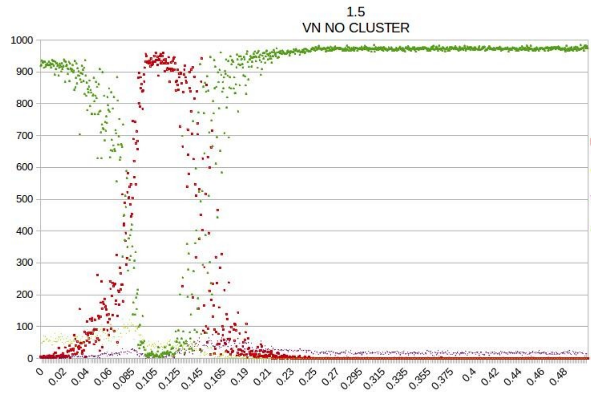

The most evident result is the huge difference between 4 and 8- neighborhoods. For small *k* levels, the plots show the presence of a unique outcome for any run for 8-neighborhood case, with a totality of cells that turned to $E_i=1$ state ("false-enforcers"); as *k* gets close to 0.5 the outcome is no more unique, but two possible states are present, with no middle point outcome: one is a fully-compliant/enforcers result, the other is a completely non-compliant/non-enforcers grid.

On the other hand, 4-neighborhood experiments present a chaotic, non unique possible outcome, for small levels of cost, and a non-compliant/non-enforcers resolution as *k* increases.

As it appears evident in the presented plots, the position of the fanatics affects the point in the cost (x) axes that constitutes the limit for chaos in VN and the limit for bifurcation. The same kind of effect happens for the version of the code, to say the procedure order for the different experiments does not affect the shape of the outcome plots but their sensitivity to the variable *k*.

This results call for an explanation for the most interesting part of the results, to say, the completely different outcomes for Moore and Von Neumann neighborhood structure are particularly evident and require an hypothesis on the mechanism involved, which will be given in next section.

SEC 4. TRANSITIVE NEIGHBORHOOD HYPOTHESIS

Despite their apparently simple definition, based on local rules, CAs can show very complex dynamical behaviors, even in the case of the so-called elementary CAs, i.e. 1D cellular automata with two neighbors and two states. An important work on CAs as dynamical systems was done by Wolfram, who proposes a classification of 1D CAs in four complexity classes, according to the asymptotic pattern generated by the synchronous dynamics starting from random initial configurations[2]:

1. Any initial configuration converges to a fixed homogeneous state (i.e., all the cells are in the same state).
2. The limits of initial configurations are cycles, with separated simple stable or periodic structures.
3. “Chaotic” or fractal patterns, with arbitrary periods, appear.

2 This classification is empirical and difficult to apply. For example, it has been shown that the membership of a given CA even in the simpler class (1) is undecidable. However, this classification is the basis for more rigorous classification attempts. An attempt in the formalization of Wolfram's classification scheme has been done by Culik and Yu (28) who split CA into three classes of increasing complexity. Unfortunately, membership in each of these classes is shown to be undecidable a priori.

4. Breaking symmetry configurations (as gliders) and long-lived localized patterns appear.

In the light of this idea of classification, the present work will describe the results of Centola et al. Model as follows, unfolding the "Emergence" point belonging to the updated ODD Protocol[3]:

- In any procedure specification(1.0, 1.1, 1.2, 1.3, 1.4 and 1.5) Moore Neighborhood structure displays two possible asymptotic pattern, one for low level of cost ($k < 0.3$), where Class 1 classification can be seen (unique, fixed homogeneous state of complete compliance and enforcement to the norm); the second one a bifurcation possibility, where both competing outcomes are classifiable as Class 1, but at two opposite extremes (complete compliance and enforcement or defection with no enforcement). The high sensitivity to initial conditions is the determinant of this behavior, where the heterogeneity of the cells (in terms of strength s(i)) is the driving variable.

  The position in space of strong believers (clustered or dispersed) influences the level of *k* that allows bifurcations, where clustering allows a stable unique outcome for higher values of the cost variable, since the "compactness" of the fanatics stabilizes results.

- Also for Von Neumann Neighborhoods the procedure specification does not affect the type of outcome (according to Wolfram's classification), even though it does change the shape of the plots reporting the outcomes. In terms of classification, the kind of long-term distribution of the compliers/enforcers and non-compliers follows a U-shaped curve as *k* increases. For low level of cost and for $k > 0.25$, a unique, steady state of non compliance appears, so if cost is too high the diffusion of compliance is not possible because too "expensive", while for *k* levels close to zero the counter-enforcers are possible and so this cells "resist" to diffusion. This two zones are ascribable to Class 1 asymptotic behavior, while in the central part of the cost interval, more interesting thing happen, where the outcome can be described as Class 3, chaotic and non predictable. The proposed sorting is also endorsed by the absence of complete cascades of compliance in Von Neumann Neighborhood runs of the CA (in no case 100% of cells turns "compliant and enforcer")

SEC 5. MEANING OF CASCADES AND TRANSITIVITY

The magnitude of the different outcomes that are possible in the two proposed neighborhood structure calls for some inquiry over the nature of this difference. I will use the term "cascade" to depict the situation of Class 1 outcome, while a certain "degree of diffusion" fits better as description for the Class 3 outcomes of this model's CA.

This is not a common use for the term "cascade", where in many applications of CAs to social and natural phenomena, it refers to any kind of wide diffusion of some sort of event, as for fire diffusion in a forest or sandpile accumulation.[4] Informational Cascade is also used in social sciences simulations literature to describe the cases where an individual, having observed the actions of other individuals, follows their behavior regardless of her own preferences or information. Once this decision process occurs, her decision conveys no truthful information about her private information or preferences; the outcome of this process is often referred to as "pluralistic ignorance". This second use can be confusing this paper, since it deals with a CA model for social norm diffusion and stability, where the point of diffusion is precisely working according to a false perception of others' behavior. For the purposes of this study, however, I want to stress a different point in the use I make of the word "cascade", which refers to a stable state of full diffusion, in opposition to a non unique outcome for the Class 3- type, which I will call "avalanches".

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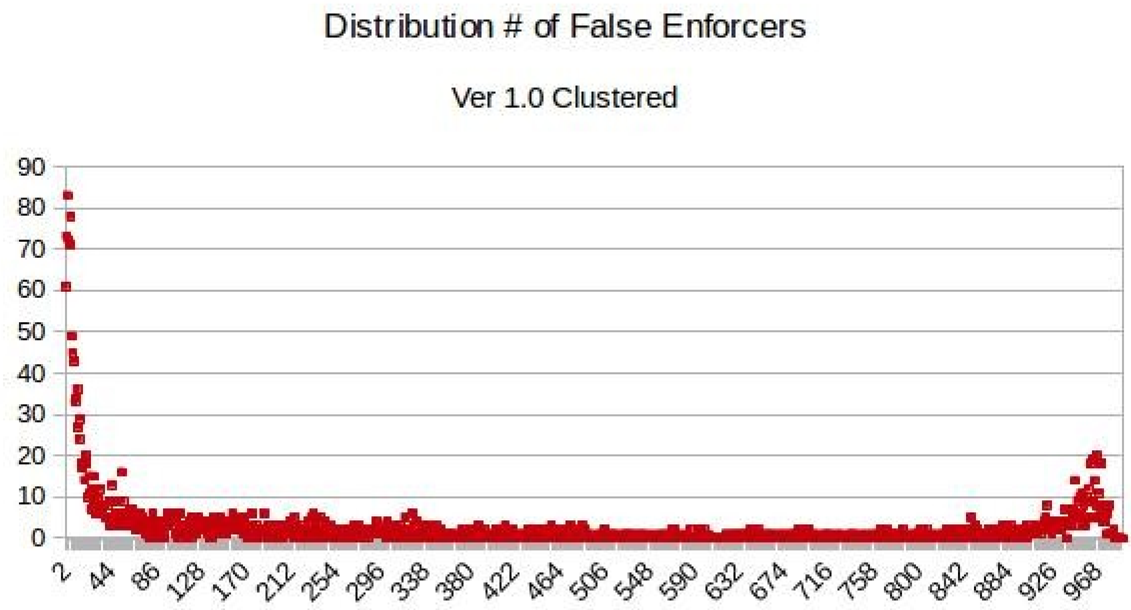
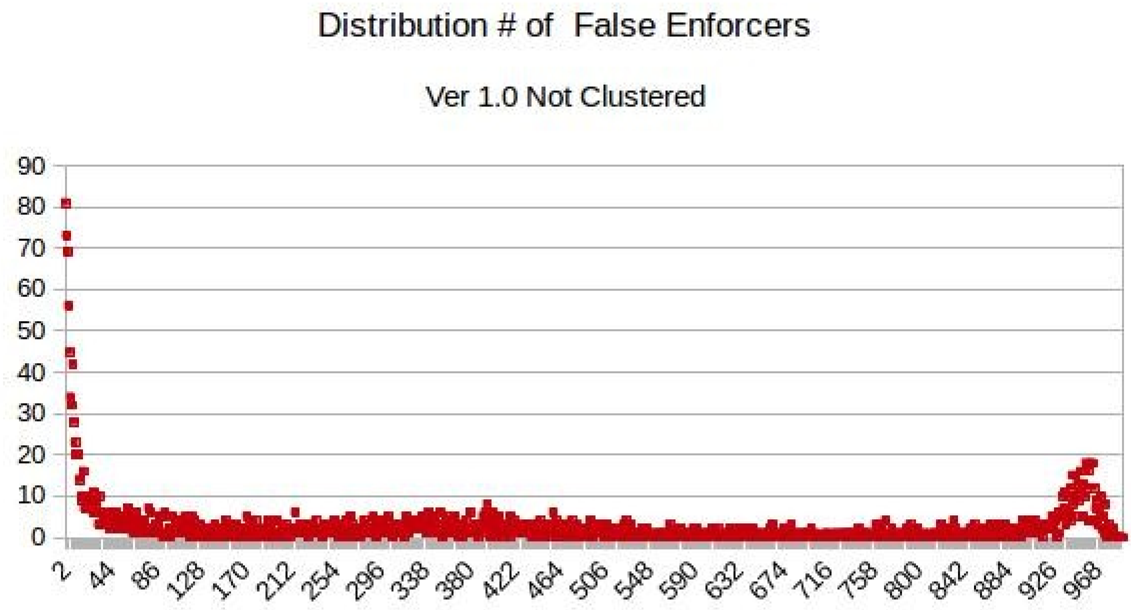
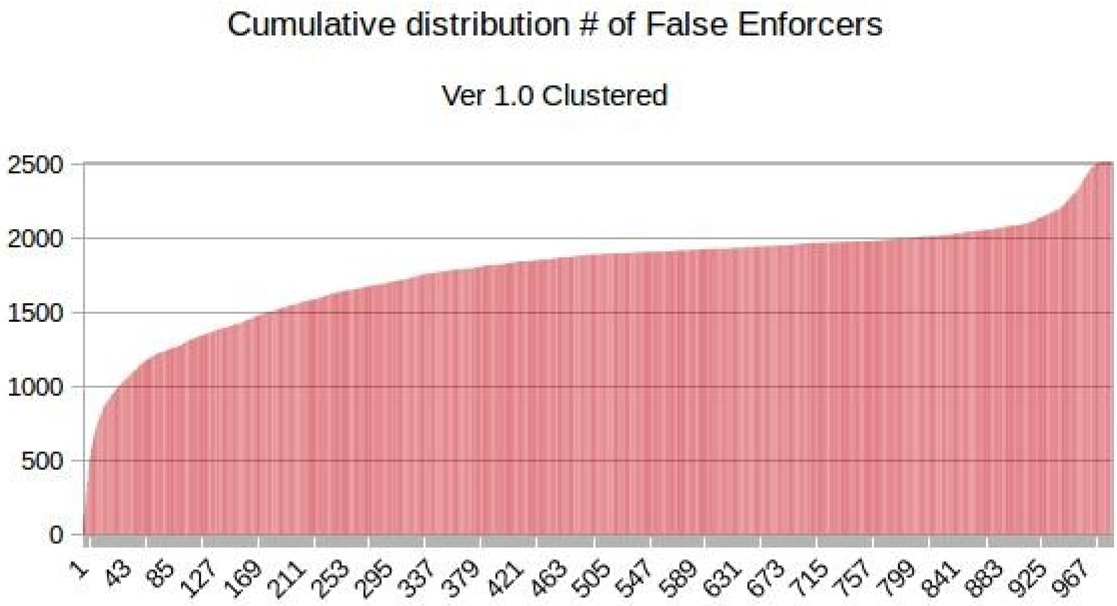
3 The Initialization point of the Update ODD Protocol was also cosidered, and it reavealed itself not to be a determinant in the simulation results, except for some trivial cases also considered by Centola et al. in their paper.

4 See Malamud and Turcotte (2000)

Along with the idea of Cascades, CAs models in general, both for social and for natural sciences, display many emergent phenomena, like for example the concept of avalanches or other events that satisfy a power-law frequency-area distribution. Some scholars have labeled this behavior self-organized critical. In self-organized criticality, the input to a complex system is constant; the output is a series of avalanches that follow a power-law frequency-size distribution. Natural hazards, like sandpile accumulation, forest fires and others exhibit a similar behavior. In this sense, Von Neumann Neighborhood results are here presented differently, where the magnitude of avalanches (x axes) is plotted in terms of frequency of the avalanches event (y axes). The shape of these curves is precisely one of a power-law frequency-area distribution, for levels of cost smaller than 0.25.






Cumulative distribution # of False Enforcers
Ver 1.0 Clustered
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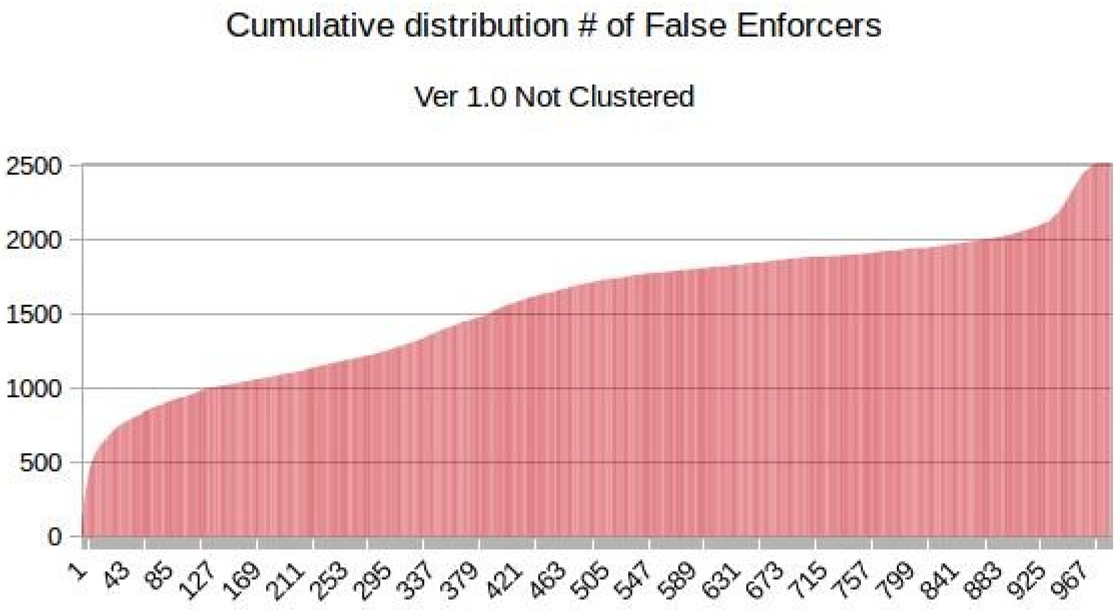
2000
1500
1000
500
0
1 43 85 127 169 211 253 295 337 379 421 463 505 547 589 631 673 715 757 799 841 883 925 967


Cumulative distribution # of False Enforcers
Ver 1.0 Not Clustered
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2000
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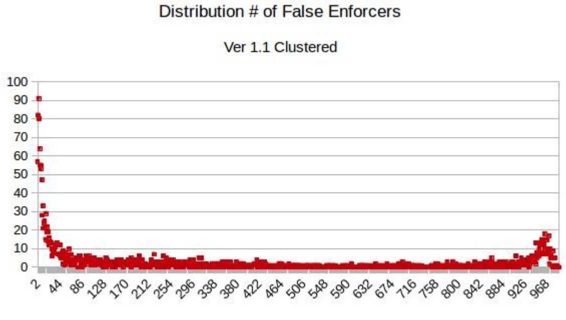
1 43 85 127 169 211 253 295 337 379 421 463 505 547 589 631 673 715 757 799 841 883 925 967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90
80
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60
50
40
30
20
10
0
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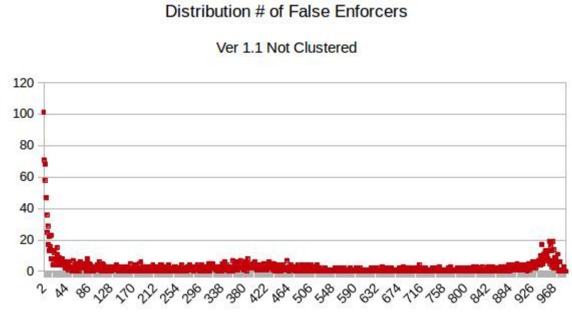
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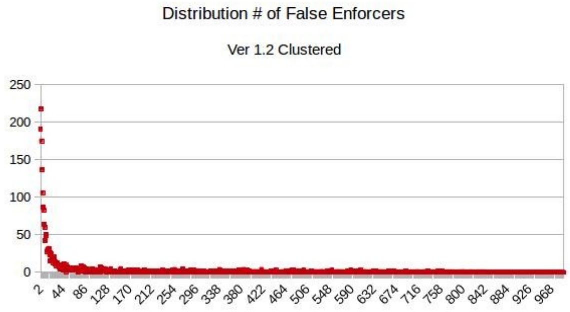

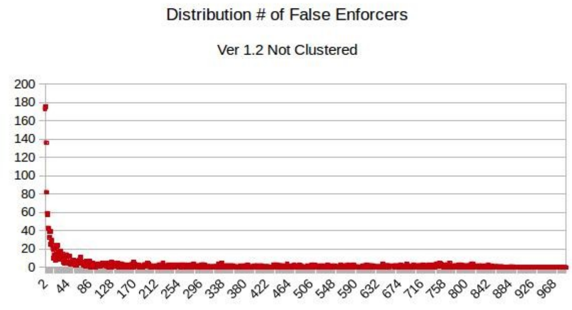

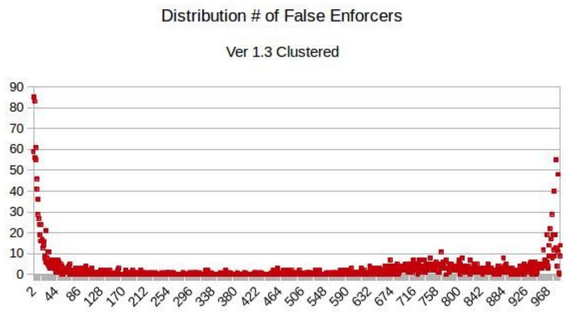

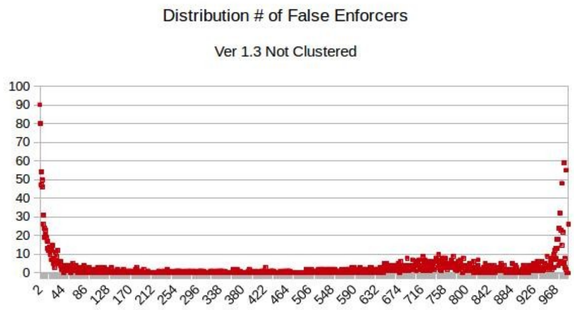

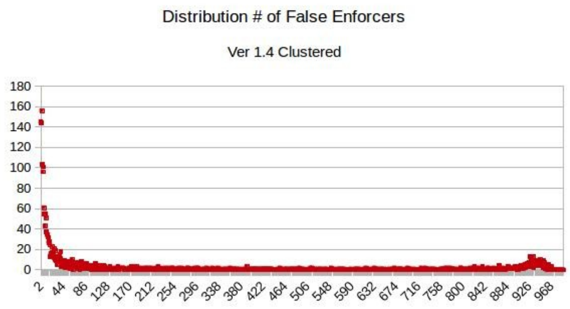

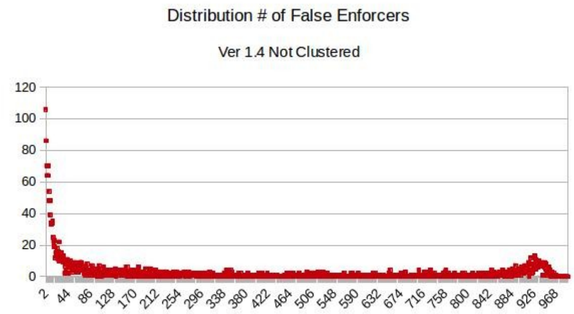

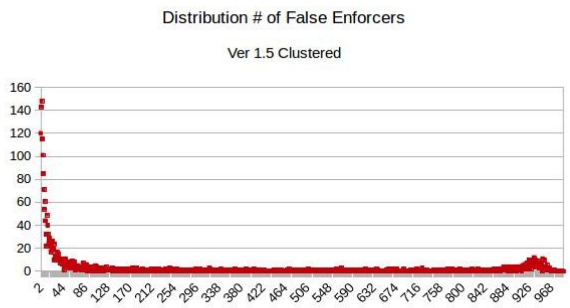

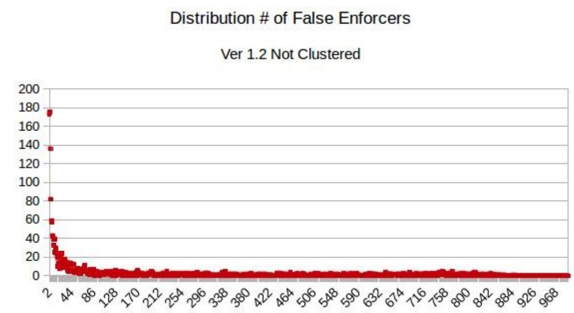

In a Transitive Neighborhood structure like Moore's, the stability of a cascade is made possible by the way transition function evaluation works in parallel with neighbors that partially share their neighbors, while this is not the case when, in Von Neumann neighborhood, each transition function evaluation works separately, creating different “sphere of influence” for each cell, and allowing for chaotic displays of states. In other words, summarizing the last considerations of this sections, Moore neighborhoods lead to the emergence of unique outcome or bifurcation of cascades, where Von Neumann neighborhoods lead to power-law distributions of avalanches, similarly to natural hazards.

SEC 6. CONCLUSIVE REMARKS

Simple, spacial models of social interactions and CAs social simulations have quite a long history, starting from Sakoda (1971) and Schelling (1971), and have had an important impact in the field of social sciences, both for their simplicity in the design and for their interesting theoretical and empirical results.

The specifications of models are, as it is known, important for the outcome, especially for some chaotic and complex phenomena that display sensibility to initial conditions; although, many of these specifications are not taken as part of the inquiry, like for example the idea of the neighborhood structure and the technical specifications of the procedures. This features, on the contrary, proved themselves to be sometimes crucial independent variable, that have to be carefully explored for a deep understanding of the outcomes, like in the case of the Centola et al. Emperor Dilemma Model analyzed in this paper.

In the case of social CAs models, like this one, transitivity of neighborhood relationships is an important aspect, like it is shown in Newman and Park (2003). as as well as the exploration of different grid structure and spacial possibilities, as Flache and Hegselmann (2001) pointed out. Using ODD Update Protocol, and carefully modifying the original model's code, this paper intended to contribute to a more robust convention in designing AB Models and Simulations for social sciences.

REFERENCES

ALLEN, P. M. (1997). *Cities and Regions as Self-Organizing Systems*. Amsterdam: Gordon and Breach.

ALLOUCHE, J. P., Courbage, M. and Skordev G. (2001). Notes on cellular automata. *Cubo, Matemática Educacional 3*, 213-244.

AXELROD, R. (1997). Advancing the art of Simulation in the Social Sciences. In R. Conte, R. Hegselmann & P. Terna (Eds.), *Simulating Social Phenomena* (pp. 21-40). Berlin: Springer-Verlag,.

BATTEN, D. F. (2001). Complex landscapes of spatial interaction. *Annals of Regional Science, 35*, 81-111.

CENTOLA, D., Willer, R. and Macy, M. (2005). The Emperor's Dilemma A Computational Model of Self-Enforcing Norms. *American Journal of Sociology*, *110(4)*, 1009-1040.

CULIK II, K. and Yu, S. (1988). Undecidability of CA classification schemes, *Complex Systems, 2,* 177-190.

CULIK II, K., PACHL, J and Yu, S.(1989). On the limit sets of cellular automata, *SIAM J. Comput., 18,* 831-842

FLACHE, A. and Hegselmann R. (2001). Do Irregular Grids make a Difference? Relaxing the Spatial Regularity Assumption in Cellular Models of Social Dynamics. *Journal of Artificial Societies and Social Simulation* 4(4) http://jasss.soc.surrey.ac.uk/4/4/6.html.

GRIMM V, Berger U, DeAngelis D L, Polhill J G, Giske J and Railsback S F (2010). The ODD protocol: A review and first update. *Ecological Modeling* 221 (23), 2760-2768. [doi:10.1016/j.ecolmodel.2010.08.019]

HEIDER, F. (1946). Attitudes and Cognitive Organization. *Journal of Psychology, 21*, 107-112.

HOFFMAN, A. O. I., Jager, W. and Von Eije, J. H. (2007). Social Simulation of Stock Markets: Taking It to the Next Level. *Journal of Artificial Societies and Social Simulation*, *10*(2), 7 http://jasss.soc.surrey.ac.uk/10/2/7.html.

KARI, J. (2005), Theory of cellular automata: A survey, *Theoretical Computer Science, 334,* 3 – 33.

LOUCH, H. (2000). Personal network integration: transitivity and homophily in strong-tie relations. *Social Networks 22*, 45–64.

MALAMUD, B. D. And Turcotte D.L. (2000). Cellular Automata Models applied to Natural Hazards. *Computing in Science and Engineering, 2(3),* 42-51

NEWMAN, M. E. J. And Park, J. (2003). Why social networks are different from other types of networks. *Physical Review E* 68(036122), 1-8.

POLHILL, G. J. (2010). ODD Updated, *Journal of Artificial Societies and Social Simulation*, *13*(4), 9 http://jasss.soc.surrey.ac.uk/13/4/9.html.

SAKODA, J. M. (1971). The checkerboard model of social interaction. *Journal of Mathematical Sociology,* 1, 119-132.

WOLFRAM, S. (1986). *Theory and Applications of Cellular Automata*, World Scientific, Singapore.

WOLFRAM, S. (1994). *Cellular Automata and Complexity*, Addison-Wesley, Reading, MA.

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