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Social crises. A network model approach

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HIGHLIGHTS

- Increase of complexity causes the appearance of concentrator, a source of disagreement.
- Preferential attachment model in endogenous crises generates exponential distributions of crises.
- Endogenous crisis scenario manifests a complex or critical dynamic.

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ABSTRACT

Crisis, conflict and complexity are concepts that are deeply related in the evolutionary history of social dynamical systems. The spontaneous increase of complexity of adaptive systems, including social systems, entails critical processes where the organization of the system, or part of it, is questioned. In this study we address the phenomenon of social crises through models of society based in networks that combine the increase in complexity with the clash of forces in conflict which could lead to a crisis for the system. The simulations suggest that there is a positive correlation between the increase in the complexity of the system and the emergence of crises as a complex phenomenon itself where its mitigation can have unexpected results.

1. Introduction

Life would be impossible without the conflict between opposite dynamic forces [1]. Complexity, conflict and crisis have always been related in the history of adaptation of systems giving shape to the world we see.

The transition from a routine situation to a state of social crisis, or fluid critical juncture [2], is determined by contingency, but also by uncertainty. Here the confluence of apparently unrelated events and the destabilizing influence of abrupt changes play an important role [3]. The relatively simple idea that we have of the crises phenomenon, collides with its complex behavior characterized by explosions of intense and unexpected activity, unpredictable resulting scenarios and complex

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temporal and spatial expression patterns [4–8]. This is why few concepts as "crisis" refer to such diverse connotations [3] for a phenomenon that seems to be common, natural and inevitable within the evolutionary history of a system in continuous adaptation.

As suggested by J. Tainter [9], the social system operates as an Adaptive Complex System [10] and, therefore, during its adaptation acquires complexity by diversifying the roles of its components and improving their combination. As a result there is creation of new norms, bureaucracy, infrastructure, social values, institutionalism, among other adjustments. According to Tainter, this complexity has an associated cost that contributes to the destabilization of the system. The traditional view that the complexity of the system would contribute to its robustness had already been questioned by works such as R. May [11] explaining the fragility of complex ecological systems. Today, new background [12–14] supports this idea, suggesting that crises in economic systems are due largely to their integration and diversification, both manifestations of the system's complexity.

Social crises have been commonly understood as processes that can lead to breaks in the functioning of institutions, not necessarily legitimate, threatening their continuity [2]. Added to this is the perception of the massive and violent character that usually accompanies them. An example of this are the recent multi-sector mobilizations carried out in different countries around the world, expressing diverse social, cultural, political and economic demands. However, crises are not necessarily violent, nor do they necessarily affect the entire system, neither they require massive participation. Critical episodes can occur in small social organizations such as a family [15] or school [16,17], as well as in larger subsystems, such as neighborhoods [18] or countries [19,20].

Considering the above, our working hypothesis is that crises are manifestations of the evolutionary dynamics of an adaptive system linked to the constant and spontaneous increase of its complexity or internal information. This increase in complexity would generate local and/or global adaptive pressures from internal or external triggering events, putting the system's capabilities at stake to find solutions. In our research we approach our hypothesis through toy models of society based in networks, using different mechanisms in which the increase in complexity and social disagreement are considered as central phenomena.

In relation to these mechanisms, social sciences have recognized in inequality and social exclusion, key factors for the increase of social conflict. The critical sociology of K. Marx [21] places the cause of conflict in the unequal distribution of private property of production goods. The comprehensive sociology of M. Weber [22,23] does the same with the unequal distribution of power (goods and values). Most of the contemporary sociology inherits these traditions. R. Dahrendorf [24,25] discovers in the unequal positioning of "authority" and "obedience" an essential variable in the tension and disturbance of society. A unique aspect is offered by L. Coser [26] in suggesting that conflict is associated with the frustration derived from "relative deprivation" that arises in the comparison of unequal expectations among actors in similar positions. In his thesis conflict would fulfill functions that would prevent the system from ossifying, generating forces for its continuous change.

A. Schutz [27] adds that the subjective perception of inequality must be considered. It emanates from the shared universes of a collective, which internalize in a common way what seems to be good, correct, just, desirable and from where inequality is perceived as certain reality. On the other hand, A. Touraine [28] warns that the unequal concentration of knowledge monopolized by a technocratic elite, generates a continuous social tension with the citizen majorities that only have knowledge of the human from the human. Particularly when facing the question of who defines what is best for society.

All these traditional theories of sociology of conflict identify inequality in its various expressions, linked to the dynamics of the evolution of social systems [29]. Today we understand that as the complexity of the system grows, these inequalities tend to be experienced and perceived in different ways (discrimination, injustice, exclusion) causing different behaviors (disgust, hostility, disagreement). Considering this theoretical background, one of the mechanisms of disagreement proposed in our model is related to the population's reaction to inequality within the system. In this case, we load the relationships between individuals with those asymmetries described above (e.g., power, authority, goods, etc.).

However, M. Dobry [2], analyzing the interactions that occur in the critical processes of the political system, emphasizes the model of Almond and Flanagan [30], who warns of the influence not only of internal variables, such as the inequality mentioned above, but also of the influence of external information.

This information acquires an important connotation today. The accelerated production of available global information and the greater access and massive use of information technologies allow a direct connection with a new reality of a world in constant change. This information converted into an exogenous variable, including the adoption of new social valuations, leads today more than ever to permanent processes of adaptation. E. Morin [31] suggests that they are not exempt from critical processes when referring to the crisis of development and discovery of the "foreign magical world". In response to this, a second mechanism of disagreement was implemented in the proposed model considering the role of external information and its propagation among the population through the system's relations.

The resulting behavior of both mechanisms of disagreement (inequality and effects of external information) will depend on the structure of the relations in the social system given by other mechanisms that increase the complexity of the system, based on the principle of selectivity of relations [21,32–34]. In this way, the structural complexity of the system is related to the internal dynamics of the disagreement of its components, understood as a social crisis.

The organization of this work is as follows. In Section 2 we present a general description of the model. In Section 3, we present the results of the simulations. Finally, in Section 4 we summarize the highlights of the study and present final conclusions and projection of future work.

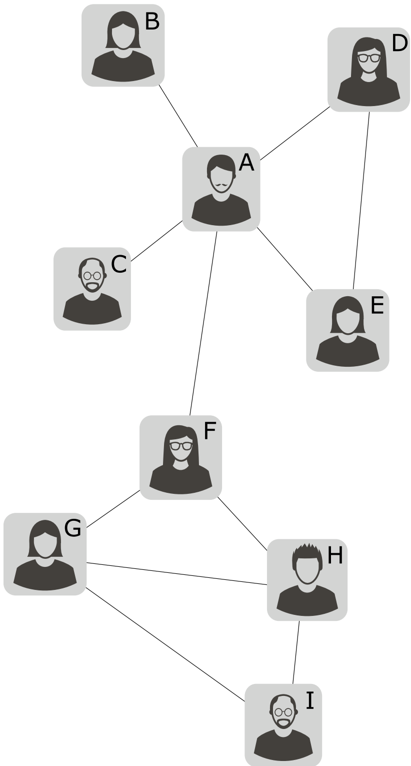

Fig. 1. Social System $S(9, 11)$. Nodes represent people and links their relationships.

2. The model

The social system toy model corresponds to a network in which individuals are the nodes, and the relationships between them, their links. The system corresponds to graph $S(I, R)$ composed of I different individuals and R relations not directed between them. Fig. 1 shows an example of a system composed by 9 individuals and 11 relationships (*i.e.*, $S(9, 11)$).

The proposed model is dynamic in two aspects. In structure because in each iteration a new node is added and generates new links, and internally since in each iteration there may be a change in the state (indifference or disagreement) of the individuals that compose it.

2.1. Structural dynamics

The model starts with a seed that will grow to a maximum size according to two mechanisms. The first one is the well-known preferential attachment mechanism (BA [35]). This mechanism assigns a greater probability of capturing the m links of the new node that arrives to those already existing nodes that have more connections. Thereby "the rich (in links) becomes richer" with the passage of time generating a network structure with an inhomogeneous distribution of connectivities. The second mechanism is the compatible attachment model, CAM [36], which is based on homophily to generate the links between the new node and the existing ones. In this mechanism, the new nodes will be linked to the older ones when compatibility exists among them. Two nodes are considered compatible when the difference between their characters x, is less than a compatibility threshold, $|x_i - x_j| < C_m$. The character x of a node is a time invariant value that represents its nature and intrinsic properties, the threshold is defined by $C_m(\tau) = \frac{d}{\tau}$, where d is a constant called compatibility distance and τ represents the size of the system. Notice that the new added node can test its compatibility with each one of the nodes present at this time in the network. Nevertheless, in the CAM the compatibility among nodes depends on the system size at this instant of the growing process. This mechanism generates an inhomogeneous distribution of connectivities as the one obtained with the BA model, but also a high clustering among other properties such as the presence of a large giant component and other small ones not connected to it.

Due to the fact that both mechanisms (BA and CAM) generate networks with similar structural properties to those observed in real social systems, the structural dynamics over time guarantee a network topology with certain complexity, key for the analysis of internal dynamics and its relationship with the complexity of the system.

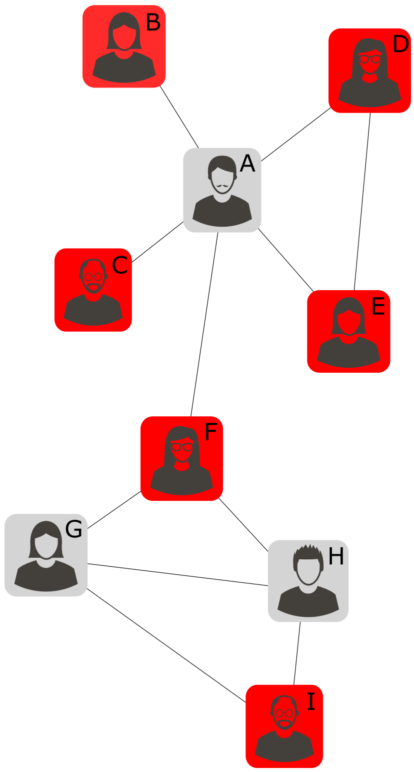

Fig. 2. Endogenous Crisis: people are in disagreement (red nodes) because of the inequality in the distribution of links. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2.2. *Internal dynamics*

The internal dynamics of the system are determined by the change in the state of individuals over time. Each individual in the system can have two states, which represent indifference or disagreement depending on the rules of disagreement described below. The state of disagreement represents the case in which the condition of the rule is met, whereas the state of indifference represents the case in which the condition is not met. The individuals in state of disagreement are for us part of the crisis of the system, as described in Section 2.3.

2.2.1. *Crisis of an endogenous nature*

The endogenous crisis is the one in which the change of state of individuals depends on properties of individuals belonging to the same the network. In particular, this model explores the disagreement related to inequality, specifically, inequality in the distribution of links, which can be translated into different types of social asymmetry (power, opportunities, money, etc.).

In each iteration the state of the individuals is evaluated according to the following rule of disagreement: *if the average of links of the neighbors of the individual i is less than the number of links of i, then that neighborhood will disagree with this distribution, moving from a state of indifference to disagreement (or maintaining the previous state of disagreement)*. It is important to emphasize that this rule supposes empathy between individuals. Individuals with the same level of connectivity as the individual concentrator of links, but belonging to a poor neighborhood of links (in average), will also disagree, empathizing with their peers.

According to the rule, the state of indifference occurs because the individual has not faced the problem (*i.e.*, the node belongs to a neighborhood in which there is no individual that concentrates links). The state of disagreement reflects the opposite, the individual belongs to a neighborhood in which there is a link concentrator, for that reason, together with his neighbors, the individual disagrees.

Fig. 2 shows the application of the endogenous crisis rule for the same system as in Fig. 1. In this case the nodes in red represent those in disagreement. The nodes [B, C, D, E, F], neighbors of A, disagree because A concentrates more links than the neighborhood has on average ($5 > 2$). On the other hand, G and H, neighbors of F do not disagree because their relationships on average are the same as F ($3 = 3$). Finally, node I disagrees because its relations (2) are less than those that its two neighbors have, G and H.

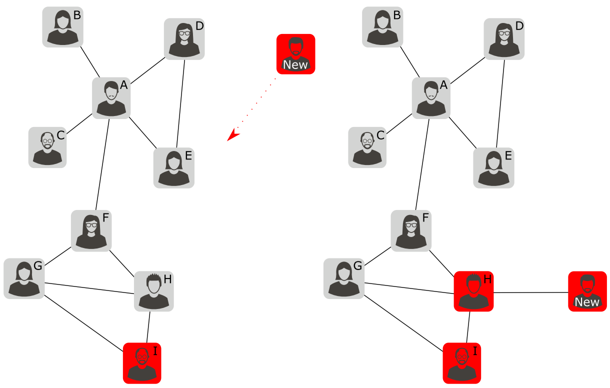

Fig. 3. Exogenous Crisis. Left: a new person (node) arrives to the system. Right: people are in disagreement (red nodes) because of the inoculation from outside and imitation. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2.2.2. Crisis of an exogenous nature

This type of crisis is the result of the disagreement of the individuals generated by the imitation of the disagreement of others (contagion) and whose origin depends on information that arrives to the network from outside (inoculation).

This type of crises have to do with the inoculation of disagreement from an external source of information that can be propagated by the following rule of disagreement: *if in the neighborhood of individual i more than half disagree, then i will imitate their state. If exactly half of the individuals disagree and the other half are indifferent, the individual i will move to a state of disagreement with a probability* $p = 0.5$*. Finally, if less than half of the individuals in the neighborhood of i disagree, then i will maintain or move to a state of indifference*. According to the rule, the state of disagreement occurs because the individual is influenced by his neighborhood. The state of indifference occurs because the individual has not been influenced by a neighborhood in disagreement.

The source of external inoculum will be the new individuals that arrived to the system in each iteration, which may come with one of the two states with a probability $p = 0.5$.

Fig. 3 shows the process of inoculation and subsequent imitation of state. In the example, the new individual arrives at the system with a state of disagreement (Fig. 3, left). Then when linking he chooses the individual H who before his arrival had a state of indifference (white). Only one of his three neighbors (I) had a disagreement state. After the arrival of the new individual he must analyze his new situation. In this case, given that half of his neighborhood [G, F] is satisfied and the other half [I, New] disagree, his status will change to disagreement with a probability $p = 0.5$ (Fig. 3, right).

2.3. Definition of crisis in the model

In the proposed model, crises are closely related to the number of individuals in disagreement. The individuals in disagreement will press for changes in the system, which can mean a change in the organization of the system unleashing a crisis. However, it is important to note that the model does not consider the potential transformation of the system as a result of pressure from discontented individuals. Nevertheless social crisis and disagreement are used as synonyms.

Since in both scenarios of crisis, endogenous and exogenous, the disagreement obeys to a single cause (inequality or contagion), we can define the magnitude M of the crisis in the system as the number of individuals in disagreement D regarding the total N, ergo $M = D/N$. In the case of Fig. 2, the magnitude of the crisis of the system is $M = 6/9$, while for the example of Fig. 3 (right) it is $M = 3/10$.

Crises can also have a local character, reaching only those individuals directly affected. This point of view tries to capture two things: (1) the possibility that a crisis only affects a fragment of the population and (2) that the crisis has multiple associated events or critical saliences as outstanding events within a scenario characterized by regularity, according to R. Thom [37]. Fig. 4 shows the size τ of local crises that affects the neighbors of Fig. 2. For example, the local magnitude of the crisis that affects the neighbors of individual A is $\tau = 5$, since there are 5 neighbors in disagreement [B, C, D, E, F] because of the concentration of links that A has.

This measure of local magnitude is only valid for endogenous crisis. For exogenous crisis, the magnitude of the local crisis will correspond to the number of neighbors in disagreement, since it is possible that not all the neighbors are contaminated with the same state.

2.3.1. Crisis management

In the proposed model, once the social crisis is unleashed, the "managers" of that system can try to control it by intervening in it. In order to simulate this action, two types of intervention or mitigation were implemented, depending on the type of crisis.

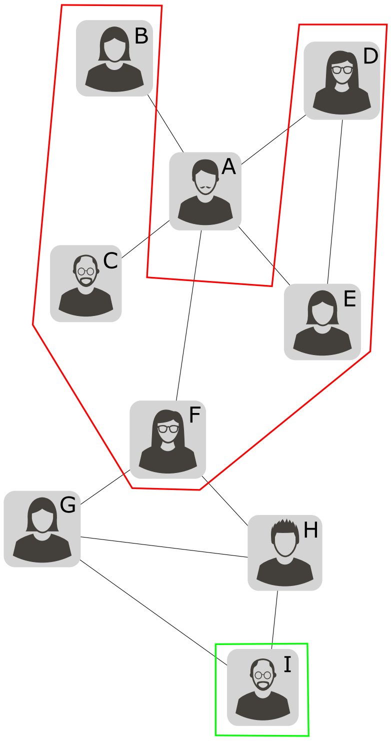

Fig. 4. Local crisis for endogenous mechanism. Color lines represent disagreement neighbors of Fig. 2.

Endogenous crisis mitigation: every *cm* iterations, 10% of the population with the highest concentration of links is identified. Once the "hubs" have been identified, and during the same iteration, the following redistribution intervention is applied: *a random portion of links was removed from the concentrators, which are redistributed among the rest of the population (except to themselves)*. The new network structure is the initial condition for the next iterations.

Exogenous crisis mitigation: every *cm* iterations, the population in disagreement state is identified. Once identified, and during the same iteration, *the state of each one of them is changed with a probability* $p = 0.5$. The new population of individuals in a state of disagreement is the initial condition for the following iterations.

2.4. Analysis of the internal dynamics of the system

The stability of the internal dynamics of the system was analyzed through the construction of Derrida Plots [38]. These are representations of the system dynamics in the transition between order and chaos with a binary state space, such as the proposed model. The method, alternative to the Lyapunov exponent for discrete systems, is based in the difference (Hamming distance) between two consecutive states of the same system when evolving according to certain rules. Through the comparative analysis of multiple initial states of the system and its temporal evolution, the Derrida Plot distinguishes three types of behavior: chaotic, ordered and complex.

The chaotic regime represents a divergent or disordered dynamic, while the orderly regime represents a dynamic that converges or that is ordered with the passage of time. Both behaviors are incompatible with the evolution of a system because they impede stability, order inheritance and the possibility of change. However, there are dynamics that are between these extremes. They are called critical or complex dynamics and present a balance between order and chaos and have been documented in genetic interaction models for species from different kingdoms [39].

In graphic terms, a chaotic dynamic is the one that is located above the diagonal in the Derrida Plot, while an ordered dynamic is located under it. A complex or critical dynamic is located right over the diagonal.

Because the proposed model is dynamic in its structure, unlike fixed-size systems for which this method is commonly used, a fixed set of individuals from the system was considered for the analysis. Fig. 5 shows this procedure.

Individuals were selected randomly from the system at a determined moment and were "isolated" to analyze their state dynamics. It is important to highlight that the set of individuals for the analysis does not lose its connections with the rest of the system, neither the internal ones. Therefore its change of state continues depending on the dynamics of the whole system.

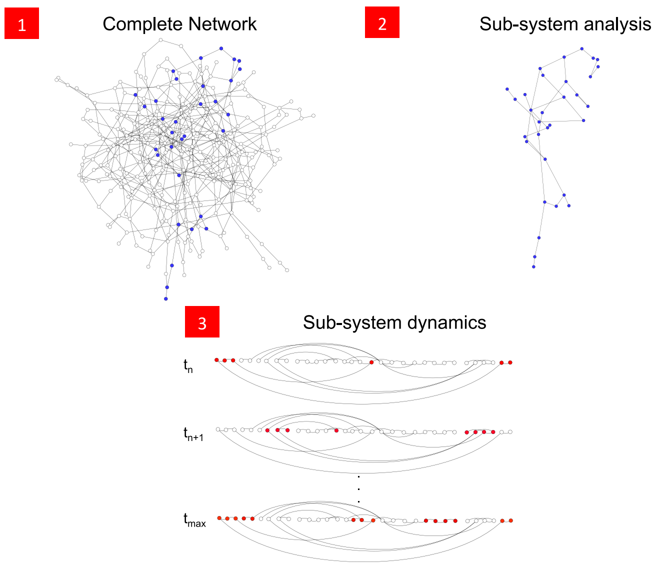

Fig. 5. Internal dynamic analysis starts with a selection of a sub-system belonging to the complete network (1) and its isolation (2) for Hamming distance analysis (3).

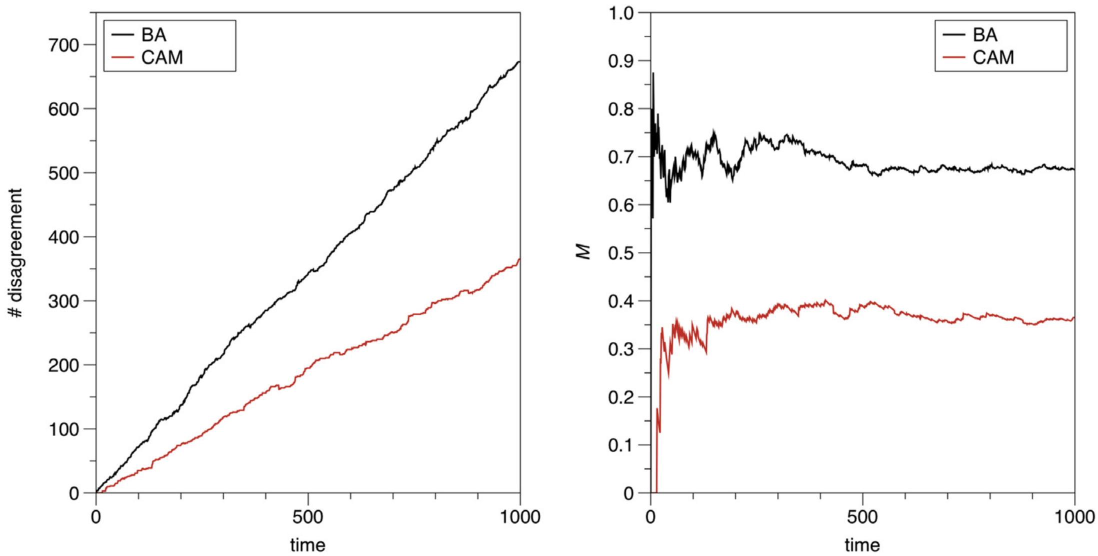

Fig. 6. Endogenous crisis. *Left*: Average number of people in disagreement over time. *Right*: Average crisis social magnitude (M) over time. BA parameter: $m = 1$. CAM parameter: $d = 0.3$.

3. Results

3.1. Crisis of endogenous character

The simulations showed a positive relationship between the complexity of the system, given by the mechanisms of growth (preferential or homophily attachment), and the number of individuals in a state of disagreement. Fig. 6 (left) shows that, for both growth mechanisms, there was an increase in the number of individuals in disagreement as new individuals became part of the system. However, the preferential attachment mechanism generated more link concentrator individuals that would make a greater number of individuals disagree, compared to the homophily attachment mechanism.

For both growth mechanisms, the magnitude of the global crisis M converges (Fig. 6, right). In the case of the preferential attachment mechanism, the crisis of the system converges to approximately 70% of the population. For the mechanism of homophily, this value approaches 35%. This shows that the mechanism by which the "rich gets richer", where those

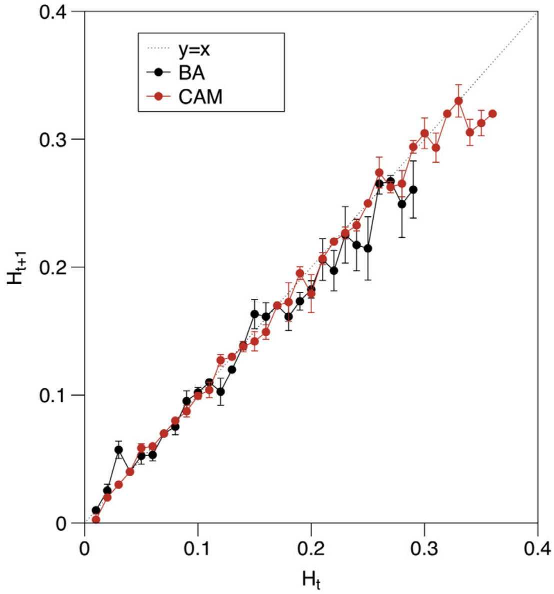

Fig. 7. Endogenous crisis. Derrida Plot for BA and CAM. BA parameter: $m = 1$. CAM parameter: $d = 0.3$.

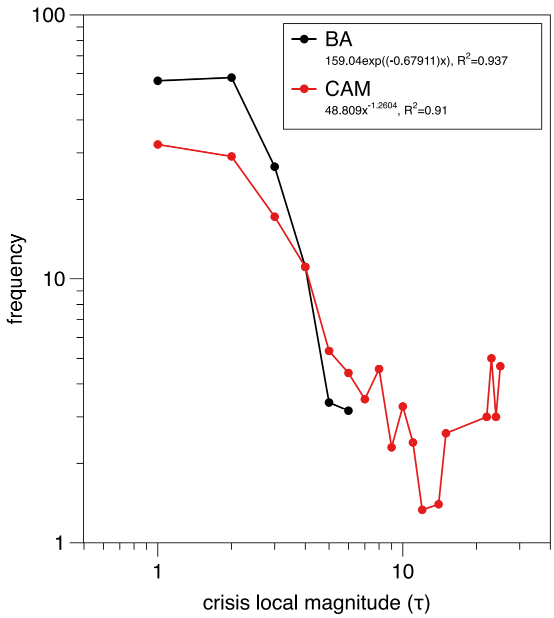

Fig. 8. Endogenous crisis. Average crisis local magnitude (τ) distribution for BA and CAM. BA parameter: $m = 1$. CAM parameter: $d = 0.3$.

individuals with more time in the system are more likely to capture links, generates higher levels of disagreement in the system than those generated by the homophily mechanism where the cumulative advantage does not exist.

Independently from the magnitude M of the crisis, both growth mechanisms generated a complex internal dynamic, where the stability of the system coexists with the transformation (Fig. 7).

In the Derrida Plot we note that in both cases the evolution is "parallel", denoting a critical dynamic, neither completely ordered nor completely disordered.

Finally, the local character of the crisis (τ) showed a qualitative difference between both growth mechanisms with respect to the distribution of the magnitudes of local crises (Fig. 8).

At the end of the process, the preferential attachment mechanism presents a distribution that is adjusted to an exponential function, where the great majority of local crises affect few individuals, being unlikely to find larger crises. On the other

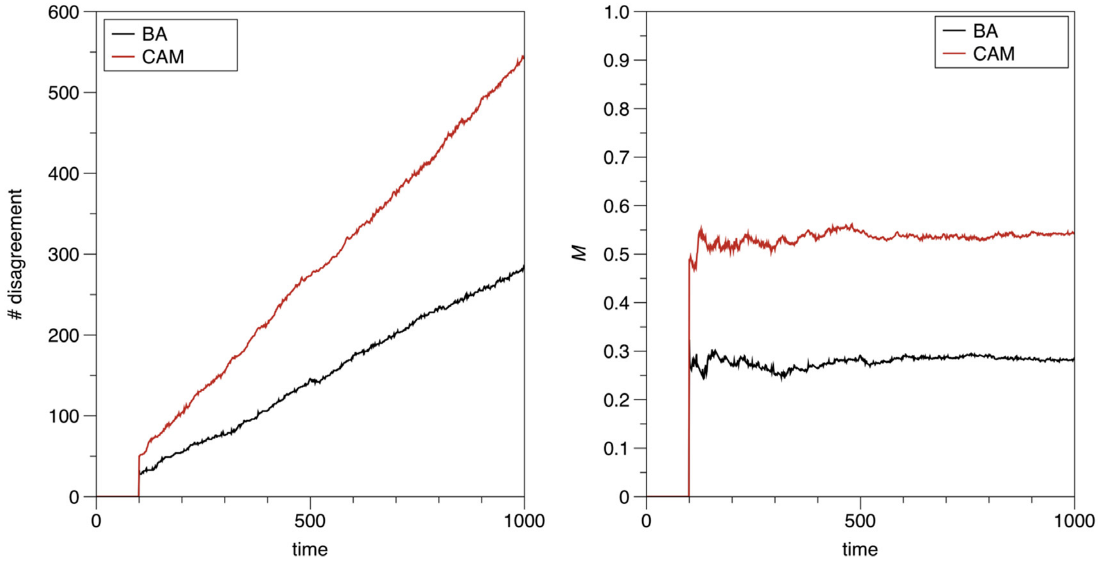

Fig. 9. Exogenous crisis. *Left*: Average number of people in disagreement over time. *Right*: Average crisis social magnitude (M) over time. At $t = 100$, a set of random nodes change their state to disagreement. BA parameter: $m = 1$. CAM parameter: $d = 0.3$.

hand the homophily attachment mechanism has a long tail distribution that fits a power law distribution. In this case, the probability of finding larger crises is greater than in the previous case and there would be a dependence on scaling between the different magnitudes.

3.2. *Crisis of exogenous character*

Following the same presentation order of results as in the case of endogenous crisis, Fig. 9 (left) shows a similar behavior to the previous scenario with respect to the positive relationship between the complexity acquired by the system and the levels of disagreement of its population. However, in this case the mechanism of homophily attachment presented a greater global crisis M (Fig. 9, right), which converges to approximately 60%, while in the preferential attachment mechanism this value reaches approximately 30%. It is important to mention that, unlike endogenous crises, during the simulation of an exogenous crisis a random portion of the population began with a state of disagreement in iteration 100, this is the reason why the curve begins at this point.

In the case of the homophily attachment the greatest disagreement in the exogenous disagreement scenario can be explained by the structure of the network generated by this mechanism. The degree distribution resulting from the homophily attachment generates a structure of the Ultra-Small World type with an exponent of scaling $2 < \gamma < 3$. Densely connected individuals play a determining role in linking a large number of individuals with low connectivity, creating short distances between them [40]. This behavior is lost for degree distributions with larger γ exponents of scaling, such as those generated by the preferential attachment.

Another difference with respect to the endogenous scenario appears in the analysis of the internal dynamics of the system. Fig. 10 shows that the homophily attachment mechanism, as well as for endogenous crises, gives rise to a complex dynamic where regularity coexists with disorder. However, the preferential attachment presents an orderly dynamic which translates into a "frozen" system without the possibility of change.

Finally, Fig. 11 shows the magnitude distribution of local crises when ending the process. It was observed that both growth mechanisms fit a power law distribution, although as in the endogenous disagreement scenario, the homophily attachment mechanism presented a greater probability of generating a larger crisis.

3.3. *Mitigation of the crisis*

3.3.1. *Mitigation in the endogenous scenario*

Mitigation has effects that are little intuitive in the case of endogenous crises. The action of removing links from the concentrator individuals and redistributing them among the rest of the population did not have greater effects on the number of individuals in disagreement (Fig. 12, left). Neither had effect on the magnitude of the global crisis M of the system (Fig. 12, right). On the other hand, with mitigation, both growth mechanisms behaved in a similar way in quantitative terms.

An unexpected effect of mitigation was observed markedly in the homophily attachment mechanism. The redistribution of links every cm iterations generated an increase each time more marked in the number of individuals in disagreement

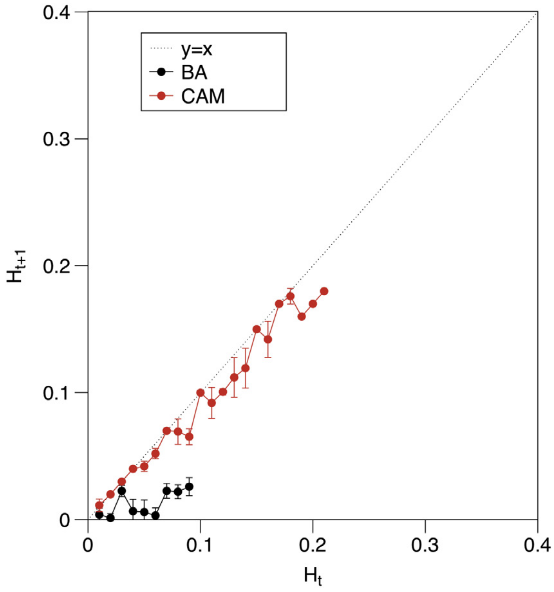

Fig. 10. Exogenous crisis. Derrida Plot for BA and CAM. BA parameter: $m = 1$. CAM parameter: $d = 0.3$.

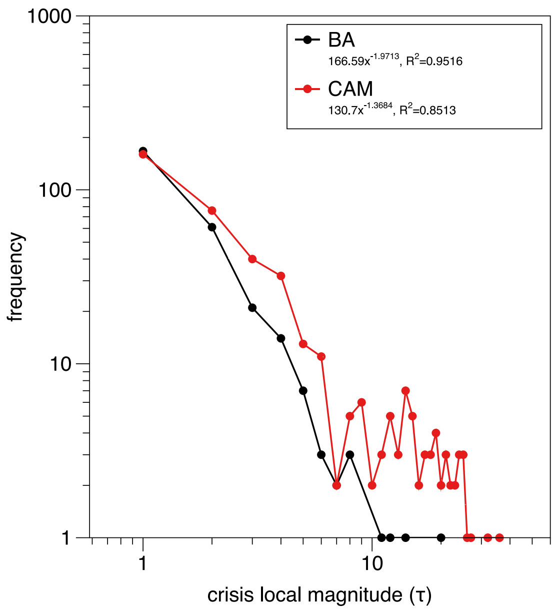

Fig. 11. Exogenous crisis. Average crisis local magnitude (τ) distribution for BA and CAM. BA parameter: $m = 1$. CAM parameter: $d = 0.3$.

(Fig. 13). The same phenomenon occurred in the preferential attachment mechanism although in a later way (Fig. 12, left, inset).

These results could have their explanation in the growth mechanism. The homophily attachment generates a large giant component and other small ones not connected to it. This is because isolated individuals form clusters by similarity, situation that does not happen in the BA model. In the case of the homophily attachment, these isolated components can become part of the major component product of the redistribution of links. Fig. 14 shows an example of this before and after mitigation.

In the example of Fig. 14, prior to mitigation, the giant component was accompanied by 120 small components composed of 1, 2 or more individuals. These components decreased by 30% after redistributing the links, which altered significantly the structure of the giant component by incorporating new individuals and links. This modification resulted in a more distributed

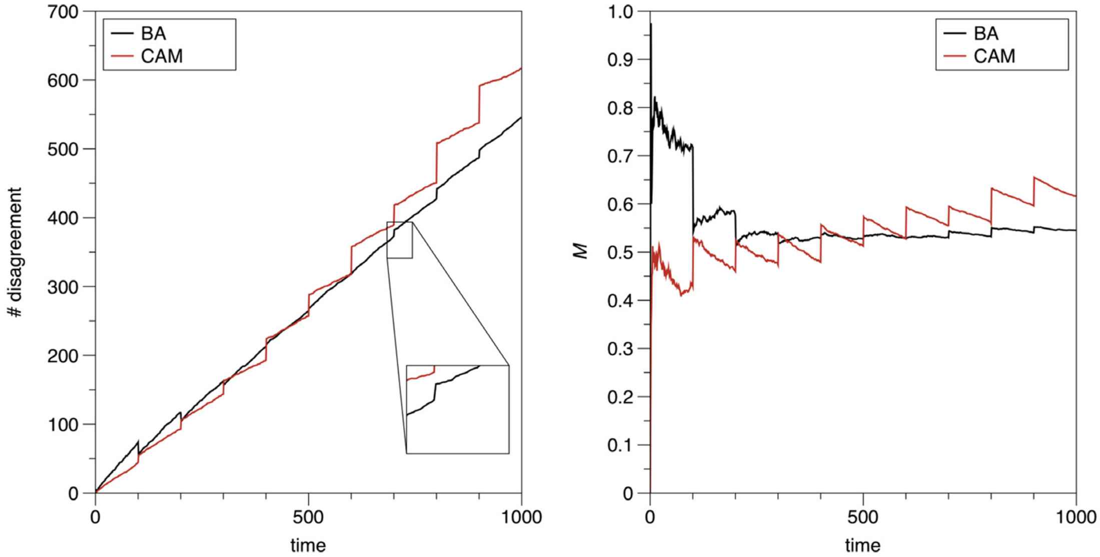

Fig. 12. Mitigation in the endogenous scenario. *Left*: Average number of people in disagreement over time. *Right*: Average crisis social magnitude (M) over time. BA parameter: $m = 1$. CAM parameter: $d = 0.3$.

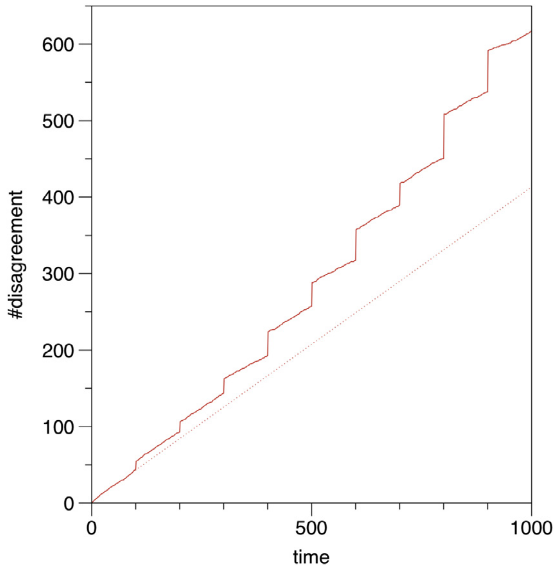

Fig. 13. Average number of people in disagreement over time. Dotted line represents the behavior expected without crisis mitigation.

network, with a decrease in its centralization [41], which went from C = 0.027 to C = 0.007. There also is a more even distribution of links, the heterogeneity [41] of the network fell from H = 0.65 to H = 0.47.

This new structure would generate those abrupt jumps in the levels of disagreement, and not a decrease as expected. The fact that this behavior appears later in the case of the preferential attachment is because the redistributions fragment little by little the only component generated by this mechanism of growth. Fragmentation occurs when removing links from the concentrator individuals that connected with peripheral individuals. Thus, these nodes of the periphery, previously connected to the single component, remain isolated. In this way, mitigation after mitigation the number of isolated components increases and the observed phenomenon for the homophily attachment is in this case reproduced.

3.3.2. Mitigation in the exogenous scenario

In the case of exogenous crises, the effect of mitigation seems to have a clearer effect. The intervention performed that changes the state of disagreement to a portion of individuals in disagreement every cm iterations, drastically decreases their number. However, depending on the growth mechanism of the population, the mitigation had different effects.

Fig. 14. System before (left) and after (right) intervention. Node size according to the number of links (degree) and node color according to the state, red = disagreement, white = indifference.

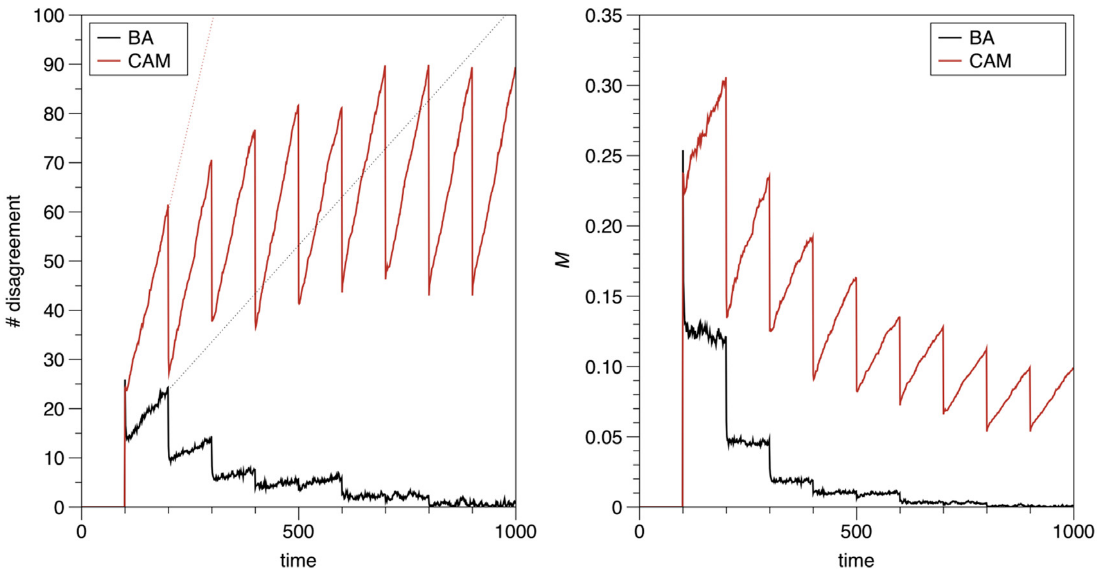

Fig. 15. Mitigation in the exogenous scenario. *Left*: Average number of people in disagreement over time. Dotted lines represent the behavior expected without crisis mitigation. *Right*: Crisis social magnitude (M) over time. BA parameter: $m = 1$. CAM parameter: $d = 0.3$.

Fig. 15 (left) shows that for the preferential attachment mechanism, doing this type of intervention has a strong effect. Not so in the case of homophily attachment mechanism in which although the effect of the interventions was notorious in the short term, it quickly vanishes. However, unlike mitigation in the endogenous case, in the exogenous crisis the mitigation did have an effect on a system that is made more complex by homophily attachment with a magnitude of global social crisis M that reached values between a 6 to 10% approximately (Fig. 15, right).

4. Discussion and conclusions

In this work a series of experiments were proposed seeking to relate the structural complexity of the social system, acquired over time, with the levels of disagreement of the population, understood as crisis. Growth mechanisms were identified for the systems and others that generate disagreement in the population were raised. Both mechanisms of growth and those of social disagreement seem to conjugate to give results that in some cases validate the hypotheses of this work regarding the connection between social complexity and the phenomenon of crises. On the other hand, despite the simplicity of the proposed models, they manage to reproduce part of the complexity observed in the manifestation of real social crises.

The growth mechanisms implemented in the society models originate a greater structural complexity of the systems. This behavior was previously documented for the proposed mechanisms. The complexity acquired over time translates into an increase in individuals in disagreement for both endogenous and exogenous mechanisms and levels of global disagreement converge in time to a maximum value. We could say that for the proposed models the emergence of crises seems to correlate positively with the topological complexity of the system.

In the scenario of endogenous disagreement the preferential attachment generates a greater number of individuals in disagreement and greater global magnitude for the crisis. This shows that this mechanism of increase of complexity causes the appearance of concentrator individuals, source of disagreement for this type of crisis. The growth mechanism by homophily attachment would attenuate the levels of social disagreement in this type of crisis by inhibiting the appearance of those super-link concentrators generating a more distributed structure.

However, this is reversed in the scenario of exogenous crisis. The greater number of individuals in disagreement and the greater global magnitude of the crisis generated by the homophily attachment can be explained by the distribution of connectivities created by this mechanism that result in a highly efficient structure in the contagion of an exogenous idea (Ultra-Small World topology). From a sociological point of view, there could be another way to explain the phenomenon.

The levels of heterogeneity in the character of individuals, considered by the homophily attachment mechanism when generating the links, must be high enough to generate complex social structures such as those sought in these simulations. When individuals are very similar, which is not the case of the implemented model, any offense against their shared values systems is usually of the greatest importance [21]. Ritzer warns regarding what might happen when an exogenous idea is introduced into the system and the effects of it. Thus, the eventual rejection seems conditioned to the set of collectively internalized rules and the cohesion generated by the shared culture (social values) by these similar individuals. This does not happen in the case of a society with greater social heterogeneity. Even when they are organized collectively it is more likely that these exogenous ideas, regardless of their character, will be integrated into the system and particularly into the behavior of individuals, whether due to the imitative effect or not and to acquire the possibility of being included in the entire network.

Other results that mark differences between both growth mechanisms and their relation with disagreement have to do with the distribution of magnitudes of those events related to the crises and the stability of the internal dynamics of the system.

In the endogenous crises scenario the preferential attachment model generates distributions of magnitude of local crises that adjust to an exponential function. In this case the vast majority of crises are of a typical size and it is unlikely to find crises involving many individuals. This behavior does not match with what has been observed where the critical events that accompany social crises present an invariance of scale [5,7]. This is similar to what happens with the growth homophily attachment mechanism meaning that there is a relationship between the events that accompany social crises. In the exogenous crisis scenario, for both growth mechanisms, the frequency of the events scales as an inverse power of their magnitude, adjusting to the observed.

On the other hand, the internal stability of the system provides more background. In the endogenous crisis scenario both growth mechanisms manifest a complex or critical dynamic. This means that stability and disagreement coexist giving the social system the possibility of manifesting crises. They can be transformed into changes and subsequent adaptation, similar to what happens in complex adaptive systems of a completely different nature, also subject to evolution. In the scenario of exogenous crisis the preferential attachment manifests an orderly dynamic where the system converges towards a configuration where indifference predominates not giving an option for change.

A point of particular interest is linked to the governance processes and the adoption of Public Policies, as a way to face these challenges imposed by the system and its acquired complexity. As E. Laszlo warns [42], unlike other complex non-conscious systems which evolve by reaction transforming themselves when pressures have reached critical thresholds, human beings are able to anticipate and displace the evolution of our societies from a reactive mode to a proactive one. However, this study suggests that mitigation actions may end up not having the expected results.

Mitigation seems to have the expected results in the case of exogenous crises. The measure of control (*i.e.*, putting the disagreement in indifference state) results in an immediate decrease in the number of individuals in disagreement, although the tendency of the system is to recover the previous state. However, mitigation seems to be counterproductive in the case of endogenous crises. The control measure of redistributing the links of the concentrators results in an increase in the number of individuals in disagreement. This behavior is marked in the case of growth by homophily attachment and appears later in the case of the preferential attachment. The result shows that the redistribution (of relationships) as a measure of discontent control can have unexpected results by profoundly altering the structure of the system.

Our interest in addressing the understanding of social crises, as a property of systems in continuous evolution and increase in complexity conditions, is framed within the broad conceptions that social sciences offer us and that we try to retain as fundamental references to move forward in the understanding of the social system in its continuous demands of transformation. However, there is still work to be developed. A deeper study of the influence of the topology of the system on the dynamics of the state of individuals, exploring the effects of parameters of growth models in the crises, and the role of information in the appearance of critical events are part of future work.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper, nor with the funding received for this research.

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