

Formation and Evolution of Business Networks in Dentistry: an Agent-Based Model

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Abstract.

This study analyzed business network formation in its dynamic aspects through agent-based modeling using cellular automata. Instead of using static partner selection criteria, as usually seen in previous works, we propose dynamic partner selection criteria. A survey with more than 300 professionals in the dentistry business was conducted to evaluate a range of aspects pointed out in the literature as important in the partnering process. The data was first analyzed to check the constructs validity to then be used in the modeling phase. Results show that a structural hole has local influence and also the way it moves the individual away from the network. They also show that the more different the individuals' rationale from the rest of the network, the more distant they will be located from that network. The convergence of partner selection criteria through talk among the network members strengthens the ties and decreases the distance among them. The findings can contribute to the literature about formation and evolution of networks.

1 Introduction

Research on the network formation can become more realistic if it can reflect the real world dynamics, the interaction among network members, the way they decide to collaborate with each others, the information flows in the network, the diffusion of innovation and many other aspects are important in this process. The use of cellular automata and agent based modeling can be helpful analyzing the networks dynamics, taking into account several of these aspects.

Epstein e Axtell (1996) argue that few attempts have been done in order to bring cybernetics concepts, cellular automata, distributed artificial intelligence, genetic algorithms and artificial life to the social sciences. The traditional approach based on phenomenological laws explains the combination between previous conditions and the result of the phenomena. In the last decade, social sciences philosophers have began the development of a different approach to the explanation, based on causal mechanisms instead of laws (BEED; BEED, 2000; CEDERMAN, 2003; EPSTEIN; AXTELL, 1996; MACY; WILLER, 2002; SAWYER, 2002, 2004). With this, models of emergent computation, such as the one explored herein, has had an increasing role.

The cellular automata were already used in the social sciences to understand cluster formation (SCHELLING, 1978) and analysis of cooperation (AXELROD, 1980) but much more can be done. The main purpose of this paper was to apply these ideas to the analysis of business networks in dentistry. A survey was conducted to determine how professional in this area think about partnering with other similar professionals and these data were used in the simulation of the evolution of networks

Macy e Willer (2002) afirm that some sociologists do not completely appreciate computational methods and relational modeling as tools for theoretical research. For the authors, *agent-based modeling* (henceforth, 'ABM') basically differs from prior use of computation in sociology because it considers interactions, instead of simply proposing algorithms and equations to represent behavioral processes and forecast outcomes. Agent-based modeling is a computational method that allows the creation, analysis and experiments with artificial societies composed by

agents that interact in a local and non trivial way, constituting their own environment in an emergent fashion (CEDERMAN, 2003; EPSTEIN; AXTELL, 1996; GANGULY et al., 2004; MACY; WILLER, 2002; MITCHELL, 1994; NAGPAL, 1999; SAWYER, 2002, 2003).

ABMs are based upon four premises. Agents are autonomous, i.e., they are not linked to a centralizer global entity. The system is composed by local interactions and self-organizes itself. Take as an example a group of birds flying in random positions, that react to local differences of speed and distance and generate in the following moment a global structured pattern. Agents are also interdependent and can relate with each other through persuasion, imitation and learning, reacting to the specific stimulus. Agents follow simple rules, global complexity does not necessarily reflect individual complexity. Agents are adaptive, consider the past and do not act following the most efficient reasoning (HOLLAND, 2001; SAWYER, 2004). ABM relies on a set of computational agents (with internal states, behavior rules and parallel operation) and their environmental specification; the communication among them is made by rules, specifying a network of connectivity that is activated through the agents' interaction and observing the emergent macro behaviors (EPSTEIN; AXTELL, 1996; SAWYER, 2003). These characteristics are essential to understand the network evolution dynamics, because individual attributes, i.e., individual decisions regarding partner selection criteria, may change through information exchange during the interactions, evolving in time.

As it was already stated, the main objective of this study was to analyze the dynamic process of partner selection in business network formation in Dentistry starting from a set of characteristics of potential partners. We used *cellular automata* (henceforth, 'CA'), a specific MBA tool, to model the dynamic process of partner selection in business network formation in the dentistry context, starting from a set of characteristics of potential partners; a secondary goal was verify the influence of interactions among the network dentists in the alliance dynamics, the dynamics of cooperation. Business networks in dentistry are characterized by personal interactions and mouth-to-mouth indications. Specifically, first we look at which variables are involved in how dentists select their colleagues of distinct specialties so as to form a social/business network that allows, for instance, the redirection of a patient with special needs, beyond a particular dentist's expertise, to another dentist of the network, so that the patient can be better served. At the same time we analyzed how dentists make their choices in building up a business network. Then, a CA-based model is developed to explain some aspects of the network creation and overall phenomenology.

This article analyzed business network formation in its dynamic aspect, its focus is not only the partner selection requirements, but also verifying the way opinions and consensus form and how the system evolves in time. This study contributes to Network Theory in what deals with strong ties influence in the consensus formation in the network, verifying the influence of a structural hole in the network and how weak ties form. It contributes also to the understanding of how the innovative potential can be suppressed in networks where their participants are connected through strong ties. It also allows to identify opinion leaders. As a contribution to the practice, this study explains how the reasoning structure and individual positioning in a network can affect decision making and what is the possible outcome to a specific posture in the network. This study can give the manager a better understanding of the creation and evolution dynamics of business networks, frequent initiative in the pursue of better performance in the firm.

The next session presents a literature review, being followed by a presentation of the research methods employed. Subsequently, the results obtained are shown and discussed, and then conclusions are drawn.

2 Theoretical background

Granovetter (1973) discusses the macro influence of strong and weak ties in the diffusion of influences and information in the community organization. The strength of ties depends on the amount of time spent, emotional intensity and reciprocal services. Actually, some of Granovetter's observations are contested by authors who argue that there are structural and cooperative imperfections in the information transmission to the decision making (FRENZEN; NAKAMOTO, 1993). Network structure can generate a market imperfection at the macro level because the information may not reach some actors, due to the lack of a communication channel, a situation that is referred to as a *structural hole* (BURT, 1997).

Communication diminishes social distance among individuals and induces cooperative behavior (BOWLES; GINTIS, 2000). In spite of common particularities among actors, even if there is a distance among them (that is, the discrepancy of some characteristics), they may become conscientious of mutual existence, and, consequently, start communicating with each other. This situation comes from a mutual interest and may develop a relationship. Multiple interactions lead to activity links between actors. However, the interactions might demand changes that create mutual dependence and opportunity costs (FORD *et al.*, 2003). This mutual adaptation is relevant to this study because it may cause a convergence of characteristics among actors motivated by the idea of completing the initiated enterprise. This convergence might be artificial in the sense that different individuals may relegate certain aspects of their opinion in order to interact with others, that is, they do not alter their conviction, just adapt themselves to the partner.

The strength of ties among partners was measured herein through the product of the number of clients indicated to the partner during a week and for how long these indications occur added by the number of clients received in a week and for how long the clients have being received. This way of measuring the construct is coherent with Granovetter (1973). The stronger the tie between two individuals, the larger the information redundancy will be and more similar the individuals will become.

The concepts of structural hole and information flow allow us to elaborate the first three hypotheses of the present study:

H1 A structural hole in the business network has local influence.

H2 The existence of a structural hole increases the individual distance to the network.

H3 The greater the convergence of partner selection criteria, the stronger will be the ties among the individuals.

Network conditions may change due to many reasons such as the strengthening of strategic position, the opportunistic learning, lack of reputation or even the development of resources initially belonging to the partner, causing an operational overlap. The smaller the relative scope of the firm involved in the network, the bigger the pursue of particular interests that increase the opportunity of the firm to access new markets not related to the network (KHANA; GULATI; NOHRIA, 1998), and may generate a social dilemma (BONACICH, 1990; ZENG; CHAN, 2003) generating instability in the network

Regarding the decision making process, Simon (1955) considered the rational choice dependence on environment effects and cognitive limitations of the decision maker. In 1978 his article starts from an initial premise that every human behavior has a great amount of rational component and that economics is concerned with the outcome of rational choice instead of considering the decision process in itself. However, Harvard (2004) argues that the empirical support to Rational Choice Theory is superficial and the Matching Law maybe is the most important competitor to explain the rational choice, as it considers not only an isolated event or an internal process of the organism, but also series of events observable in time. It proposes that, instead of maximizing utility, an individual's behavior is conducted in activities according to the value of each one, a situation that supplies a "powerful explanation" about impulsive behavior and that can also be used in the understanding of "biological phenomena", such as "natural selection [...] and economic decision making".

Herrnstein (1990) argues that the environment models individual behavior and vice versa. The social structure can affect the cognitive individual structure and consequently the behavior, in a way that entails both factors to interact in order to converge individual beliefs and preferences in group choice (FRENZEN; NAKAMOTO, 1993; NOOTEBOOM, 1999). These ideas lead to the formulation hypothesis four:

H4 The larger the distance between individual and network rationale the larger the tendency to the individual to move away from the network.

The decision making event is influenced by individual impulsiveness. Impulsiveness can be defined as "a trend to respond quickly to a given stimulus, without deliberation or evaluation of consequences" (GERBING; AHADI; PATTON, 1987); it can also be regarded as a behavioral choice that would never have been taken if its long term consequences were considered (Rook; FISHER, 1995).

An impulsive individual has higher response speed. The Matching Law relates response speed with response tendency, reinforcement and sensibility to the behavior reinforcement.

Leadership is considered a critical factor at the onset of transformations in organizations. Social networks are characterized by decentralized power and individuals' quest for common interests. In this context, leadership is not exerted by a particular individual, but shared by the whole network profile, similarly to the concept of transformational leadership (MULLEN; KOCHAN, 2000).

The characteristics of the transformational leadership remains a controversial issue. Contrarily to transactional leadership that uses rewards and punishment to monitor behaviors, the transformational leadership acts beyond the exchange process and includes four distinct factors: charisma, inspiration, individual concern and intellectual stimulus.

We presented the basic theory from which the model was developed. This study considers the theory in the determination of parameters, initial condition of the model and the interaction rules among the network actors. The next section discusses the methods including the explanation of the modeling process and the two remaining sections present the research results and final considerations.

3 Research methods

3.1 Cellular Automata

Cellular automata are a tool of MBA and were conceived by Stanislaw Ulam and John von Neumann. They are finite state machines that use an abstract method to analyze the simultaneous execution of local rules from where a global pattern emerges (HEGSELMANN; FLACHE, 1998; WOLFRAM, 2002).

CAs have three characteristics: parallelism, local interactions and simplicity of basic components (SIPPER, 2004). Due its simplicity and enormous potential of modeling complex systems, they are very often used. CAs can be seen as a simple model of a spatially decentralized system, composed by individual components, the cells.

Communication among cells is limited by local interaction. Each cell has a specific state that varies according to local neighborhood states. First a regular network, discrete, finite, that represents the universe of the spatial structure of the CA, and after that, a finite automaton, a copy that represent each node of the network. Each node is called cell and will communicate to a finite number of cells, the neighborhood, uniform composing the lattice. This communication is local, deterministic and synchronic, determining the global evolution of the system, along discrete time steps.

Evolution is determined by the previous cell state, its neighborhood and the transition function, i.e., the rule (GANGULY et al., 2004; SIPPER, 2004). When the rule is identical to all the members of the population, the CA is called uniform. The state refers to the value of a single cell. The configuration refers to the existing states in the lattice in a moment t (GANGULY et al., 2004). These rules, according to the lexicographic classification, will generate the future states of the cell (Fig. 1). Fig. 2 illustrates an elementary cellular automaton, composed only by "0"s and "1"s. The lattice has $N = 12$ cells, radius $r = 1$ e $k = 2$ states, where the cell $X = 0$, in a neighborhood $1 0 1$ in a time step t_n , become $X' = 1$ in its following state t_{n+1} . The last cell in the right consider as neighbors the one in its left and the first cell on the left, generating a round periodic boundary condition (Wolfram, 2002), illustrated in Fig. 3. For each neighbor, there are two states, 0 and 1 and eight possible neighborhoods or states transitions, creating 2^8 possible rules in space that define the *elementary state*.

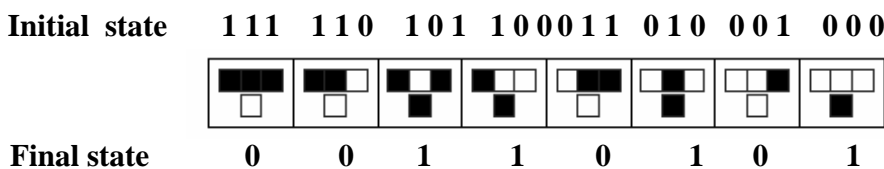


Fig. 1. Example of eight possibles states of cellular automaton rule 53.
Source: Authors.

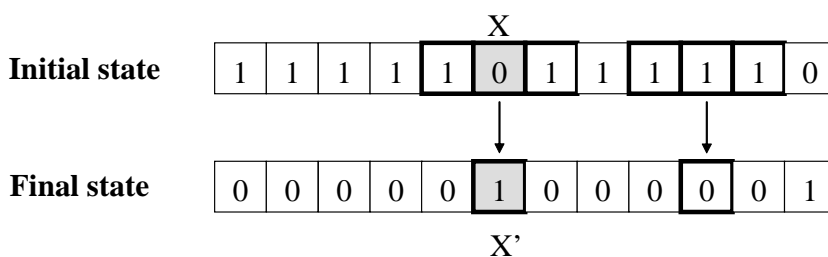


Fig. 2 – Evolution of lattice under application of rule 53.

Source: Authors.

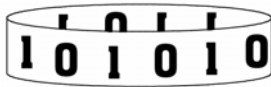


Fig. 3 – Periodic boundary condition.

Source: Authors.

Simultaneous execution of a simple rule in all lattice cells may cause the emergence of a global complex pattern (GANGULY *et al.*, 2004), what is interesting, because each individual has only access to a local neighborhood and, however, join in long distance communication and integration to complete its task (KOZA *et al.*, 1999) in a transitivity principle, also proposed by Granovetter (1973), that characterizes a connectionist system.

CAs are used in the social sciences to understand cluster formation (SCHELLING, 1978) and analysis of cooperation (AXELROD, 1980).

3.2 Variables used in the research

The strength of ties among partners was measured herein through the product of the number of clients indicated to the partner during a week and for how long these indications occurred added by the number of clients received in a week and for how long the clients have been received. This way of measuring the construct is coherent with Granovetter (1973).

The business scope was measured herein by summing the amount of specialties offered, number of employees, number of work days in the week, and number of clients treated in a day. Additionally, network scope was measured by the amount of specialties involved in the relationship, in both directions.

In respect to partner selection, George and Farris (1999) argue that firms tend to make partner selection based on easily observable technical criteria, ignoring or underestimating personal compatibility criteria, important in initial stages of network formation and stabilization. Some criteria were chosen to be tested in our network modeling according to some authors, listed below with their corresponding choice criteria:

- Partner's reputation choice was based on authors such as Al-Khalifa and Peterson (1998), Arrègle *et al.*, (2003), Fitzsimmons and Fitzsimmons (2003) and Geringer (1991). This construct was measured following the idea of characteristics that define the reputation, which are: strategy quality, products/services quality, management quality, market orientation, innovation and financial strength.
- Similarly, partner's proximity choice was based on Al-Khalifa and Peterson (1998), Geringer (1991) and Fitzsimmons and Fitzsimmons (2003).
- Expected partner's quality was measured by the technical knowledge, physical facilities and employees appearance, equipments, attention provided to the client, employees courtesy and

availability to helping the client (ARRÈGLE *et al.*, 2003; FITZSIMMONS; FITZSIMMONS, 2003; GERINGER, 1991; HITT *et al.*, 2000).

- Financial conditions offered by the partner to the client were defined as financial options and charges (FITZSIMMONS; FITZSIMMONS, 2003; GERINGER, 1991; HITT *et al.*, 2000; JUHANTILA; VIROLAINEN, 2004).
- Resources complementary choice was based on Geringer (1991), Hamel, Doz and Prahalad (1989), Cullen, Johnson and Sakano (2000), George and Farris (1999) and Hitt *et al.* (2000).

Impulsiveness is considered a moderating variable, as long as it intervenes in the decision making process. The variables used to measure the construct – namely, the time spent to analyze the situation, level of emotion in the decision, degree of risk aversion, planning time and degree of qualitative and quantitative analysis of the benefits generated by the network participation – were all derived from Doz and Hamel (1998), Gerbing, Ahadi and Patton (1987) and Rook and Fisher (1995).

Leadership is a variable that has influence over the network profile and probably moderates the individuals decision making process. It was included in the research but only the transformational characteristics were included. It was measured through the perception on the leadership characteristics of the partner.

The structural hole and its local effect will be measured evaluating the distances among the network participants.

3.3 Data collection

The sample was composed by dental offices located in São Paulo city, where, according to the Regional Council of Dentistry database (CROSP) there are 17571 dentists in 2005, when data was collected.

The sampling process was a snow-ball type, i.e., starting with CROSP's database and then using the respondents' indications. More specifically, invitations (for questionnaire answering) were initially sent to a randomly selected sample from the database, composed by 2200 letters and 960 emails. After that, the respondents were thanked by writing, where the opportunity was used to request from them the indication of potential new respondents. This procedure was repeated until a useful sample was reached, in the case 313 dentists; from these, 240 came from those directly contacted and 73 from the respondents' indications.

As an instrument to data collection, the questionnaire was hosted in a website. A Likert scale type (MALHOTRA, 2003) from 1 to 6 was used so as to avoid a neutral positioning of the respondent (KERLINGER; LEE, 2000).

Before the actual research a pre-test was carried out with 30 individuals, which helped to improve the questionnaire; the pre-test respondents were not considered in the final sample. The questions measured the variables we intended to study. In the beginning of each section of the questionnaire, we included an explanation in order to clarify the theme. Questions regarding different constructs were mixed in their order of appearance and negative assertions were included so that we could decrease a vicious answering (SCHWAB, 2005).

Four respondents were excluded from the sample due to an excess of missing values, as they might compromise the modeling and statistical analysis. Eighteen questionnaires had a small amount of missing values, and were completed by the valid sample average. The option for accepting incomplete questionnaires was appropriate, as it prevented the respondents from giving up answering. Furthermore, four outliers were identified. The model was run with and without the outliers.

3.4 Data processing

After preparing the data, a factorial analysis, limited to 10 factors and Varimax rotation, was run and the principal components extracted.

The factors obtained from factorial analysis explained 47,81% of the variance. The factors were orthogonal and had a Kaiser-Meyer Olkin sample adequacy measure of .587 and the result for the Bartlett Sphericity Test of 1865.52 significant at .000. The maximum Spearman's correlation among factors was 0.151 significant at 0.01 level, between factors 1 and 3. The outcome of the factor analysis served as variables to the modeling phase; they are listed below, together with the attributes they comprise:

1. *Leadership*: partner interest, optimism, search for alternatives, individual attention and the perception that the network increased the business strength. Cronbach's Alpha: 0.624
2. *Quality*: equipments, employees appearance, facilities, customization of service and technology. Cronbach's Alpha: 0.594.
3. *Reputation*: ability, honesty and innovation. Cronbach's Alpha: 0.483.
4. *Customer care*: proximity, flexibility, financial conditions. Cronbach's Alpha: 0.423.
5. *Propensity to collaborate*: network scope, market saturation, market competition and risk aversion. Cronbach's Alpha: 0.500.
6. *Impulsiveness*: indication by a strong tie, planning horizon, emotion in the decision, persistence and invested time in the decision making. Cronbach's Alpha: 0.456.
7. *Network utility*: calculation of benefits, contribution equivalence and dependence. Cronbach's Alpha: 0.405.
8. *Degree of external segregation*: by importance given by a weak tie indication, elitism and hardness of the partner. Cronbach's Alpha: 0.430
9. *Decision importance*: involvement and quantification of risks prior to the partnering. Cronbach's Alpha: 0.403
10. *Decision value*: egotism, complementary of resources, costs and risks of Dentistry practicing. Cronbach's Alpha: 0.415.

3.5 Implementation

Once we had the 10 factors, data was classified following the leadership factor, so that the individual that identifies the partner the most as a leader became the *pivot*. The remaining individuals were placed to the right of the pivot, in decreasing order of the value of their leadership factor, so that the individual that identifies itself the least with the leader ends up at the left-hand side of the pivot, since the model has periodic boundary.

Different scales of factor values were transformed into a single scale from 0 to 255. After that, a distance measure was computed between every individual and the pivot, according to the individuals' factor values, by means of the expression:

$D_{i0} = \sum_{n=1}^{10} (X_{ni} - X_{n0})$, where X_{ni} is the n^{th} factor X of the i th-individual and X_{n0} is the n^{th} factor X of the pivot.

After that, it was used a threshold scale to represent decimal values of factors in a binary way. The threshold scale was composed by classes and their number was defined by Sturge’s rule: $C=1+3.332*Log_{10}N$ (CARLSON; THORNE, 1997), where N is the size of the sample, 304 individuals. The Sturge’s rule application led to 9 classes, defined by intervals of 28.333.

Factor values of each individual were then converted to a binary number of 9 digits, following the threshold scale. Binary values were positioned in their threshold interval, so that the interval containing a factor value was assigned bit 1 and the others, 0. For example, an individual with a value of 43.3 would have a value 1 in the second cellular automaton and 0 in all others. 0s and 1s were determined with the following condition:

If $\min \leq f_v < \max$ then $j_n=1$, else $j_n=0$, where f_v is the factor value for individual i and j_n is the n^{th} cell in the n^{th} cellular automaton.

Nine ECAs with 304 cells were then created, each of them corresponding to one threshold interval and every individual was composed by 9 cells. The initial state of the ECAs were then obtained. The dimension chosen for the neighbors, 1 of each side, was selected to preserve information quality. With such an approach a society connected through strong ties has thus been created, in accordance with Chwe (1999), who argues that strong ties are better in the creation of common knowledge, an essential feature to collective action.

In order to select the most appropriate rule to run the model, a rule was chosen in a way that allowed more than 10 interactions, converged in less than 308 interactions, that have a transient not too long and that converged to a fixed point and not a cyclical attractor. These conditions were determined due to the computational limitations and to make data analysis possible. Rules that converged to fixed point in less than 10 interactions were eliminated, as well as fixed point and chaotic rules. The selection criteria also considered the possibility of rationalization of the rule, in that the rule could be translated into a coherent action with the theory (see below for an example).

The chosen rule was rule 234 (Fig. 4), out of the 256 possible ECA rules; in addition to meeting all requirements, it embeds the rationale that an individual’s opinion follows the local majority, but if the individual’s opinion is different from the most influential neighbor (i.e., the one in the leftmost position) and the opinions of neighbors are the same, the individual changes his original opinion and turns it to the same of the neighbors.

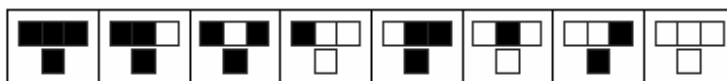


Fig.4 Rule 234 and the state transition that define it.

The stop criterion of each ECA was established by the state updates converging to a fixed point or reaching the 308th iteration. At that moment each column of the lattice, i.e., individual values,

was converted to a decimal number following the average class intervals that contained numbers 1 following the equation:

$$\sum_{n=1}^9 j_n i^* AC_i$$
 with $1 \leq n \leq 9$ and $1 \leq i \leq 304$ where AC_i is the average class interval, j_n is the value of the n^{th} CA, n is the number of classes (CA) and i is the individual.

The final distances relative to the pivot were measured just like initially done. Over than 305 interactions occurred in order to allow information flow by transitivity to all individuals, since we are dealing with a connectionist system.

4 Results

Professionals working in small dentistry organizations containing 3 to 5 employees answered the research questionnaire and the major percentage of answers (36%) came from general practitioners.

Analyzing the responses is possible to notice that only few variables were not highly considered as important as partner selection criteria. Among them are strength of ties, perception of partner elitism and price charged by the partner. Respondents have a medium to short term perspective in their decision making process, and had the perception that their partners have got transformational characteristics.

In the modeling phase each rule generated a different special positioning, thus confirming hypothesis **H4**, because according to the existing rationale in the network, entailed from the rule, the individual attributes and distances will change.

Initial distances had great variation, in the range from -250 to 250, what represents the individual differences regarding different selection criteria. The reduction of distances after rule 234 application to a range of 0.08 shows that individuals get closer to each other due to tie strengthening and an increase in the degree of similarity. There was an opinion convergence, represented by the reduction of distances among individuals, but at the micro-level they did not become exactly the same. Results are compatible with the Matching Law, because similar individuals will strengthen the tie between them and will be susceptible to constant behavior reinforcements, therefore supporting hypothesis **H3**.

Final distances showed that individual 249 was the one who modified the least his positioning, keeping himself away from the network. This individual was the least influenced by the network and increased his factor values 9 times, while the network increased 9.3 times. Analyzing the initial variables, we noticed that individual 249 does not consider partner indication by a strong tie as important, had considered more the benefits prior to entering the network, perceives that the contribution in the network is not equivalent, and takes more time than the average to decide. So he is a less impulsive individual, very rational and with low cooperation propensity. He wants to maximize his utility, perceives little value in the decision of participating in the network and is refractory to strong ties reinforcement. So, participating in a network has a small weight in his decision, what makes him a weak tie. Hence, such a finding supports hypothesis **H6**.

The increase in tie strength caused an increase in impulsiveness and a greater cooperation propensity, as long as there was the same rationale. Network's utility increased, as well as the outcome value and its importance, because according to the Matching Law, individuals are subject to behavior reinforcements. These facts confirm hypothesis **H5**.

For all factors there was a convergence in zero, that is, everyone perceives that artificial network formation increases each business strength. The reputation factor was the only one for which there was a convergence in two clusters. The smaller one was composed in its extremity by individuals 33 e 173 and its size was 85% smaller than the other. In order to know who was the individual that attracted the others to the second cluster, we analyzed both. Individual 33 does not see his partner as a leader, differently from individual 173. So, individual 33 is farther from the pivot. The larger discrepancy in the factor values happened for individual 33, suggesting that he is the one that changes his opinion the most. We concluded that he is the source of influence that moves away the adjacent individuals, up to individual 173. Those adjacent to 33 to 173 do not receive the information because 33 alters the quality of the information transported. However, individuals from 173 and beyond converge to zero because the CA has periodic boundary, that is, the pivot interacts with distant network layers. The periodic boundary shows the importance of the manager to be in contact with employees in order to spread his influence to the different layers of the organization and of the network.

The insertion of a structural hole using rule 204 in the 150th individual, that is, an individual that did not change his opinions along the interactions moved away individuals from the 45th to the 150th, who formed a cluster. This confirms that the information flow comes from the individuals far from the pivot influence. This happened because the 150th individual interrupted information flow. However, information flow is compensated by transitivity. That is the reason why there was only a local influence, therefore supporting hypotheses **H1** and **H2**.

In order to verify the influence of outliers that were removed from the model, we run a CA containing the four outliers. The only alteration noticed was the increase in time convergence, that turned from 199 to 288 iterations. This result is coherent because the total number of individuals was large when compared to the small number of outliers, that were not capable of altering the overall system configuration.

At iteration 26 there was an exponential threshold from where a characteristic convergence could be observed. In order to identify it properly we looked at the CA global state at that iteration. Fig. 5 shows the cellular automata configuration, starting from the top and going down. The threshold is showed by the white circle at the tip of next-to-last triangle. This threshold happens at the 26th iteration and represents the moment where the network is taken by the "rebels" (black areas), individuals that propagate their influence and represent the majority. It can be noticed that individuals far from the pivot join the network later (white triangles on the right whose size is bigger than the ones on the left). Iteration 26 determines the network threshold, where the majority of "rebels" take the network. This threshold is usually found in innovation adoption events. After 199 iterations, all the network is in consensus (black area), thus meaning that all network starts to consider quality as a relevant factor in partner selection.



Fig. 5 – CA evolution for the first CA of Quality factor.

Source: Authors

5 Conclusions

Results show that a structural hole in the network increased the distance of adjacent individuals and its influence decreases in distant neighbors. Different distances also came from different network rationale, what means that environment influence prevailed over individual decision criteria. This happened because individuals with different decision criteria were attracted to the same position through the use of the same reasoning, what suggests that the environment exerts strong pressure over the individual and that decisions are contingent.

Along the interactions there was a convergence of opinions in decision criteria, what represents the consensus appearance being formed among dentists. The distances decreased for all individuals, meaning that decision criteria similarity increased along the interactions. The increase of similarity among decision criteria caused a greater propensity to cooperate. There was an increase in tie strength among network participants, what caused an increase in their impulsiveness, compatible with the Matching Law.

Macy and Willer (2002) observe that many agent-based models treat social forms as behavioral interactions, not varying the topology and actor identities. The model explored this gap in the literature and considers topology, once it has special relevance in the modeling results (SAWYER, 2003; SIPPER, 2004). The model also considers structural attributes of the agents, the same way Tesfatsion (2005) did, but in another circumstances. In tune with latter, actor identity is varied herein, insofar as the factors change along time, since individuals do interact with their neighbors and may acquire opinions that initially might have belonged to another. Topology varied according to discrepancies of the individuals' characteristics. and was measured by the distance among actors and a chosen individual (the so called *pivot*), in the same way as Burt (1976) and Gulati (1995).

The selected area of the sample used herein may not represent the general condition of the Dentistry universe used. Therefore, conclusions may not be general to all firms of the dental sector in São Paulo city. Clippings and options done to measure the constructs chosen as important to formation and development of networks were selected following the authors' objectives and do not include all partner selection decision criteria found in the literature. Nevertheless, many interesting observations could still be made, atesting the validity and strength of the model

This study contributes to theory insofar as it allowed to verify the potential use of cellular automata to understand formation and evolution of business networks, an application that has never been explored. Emergent phenomena was observed, and there were environment and rationale influences in network configuration. This fact suggests a dynamic partner selection decision criteria classification and allows researches to understand the formation of weak ties as

well as the emergence of consensus in the network. This study contributed to the practice once it allows to understand the knowledge management in the network and the direction of information transmission.

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