Network shapes resulting from different processes of interaction

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Abstract: We propose a model of social network dynamics based on the influence of an agent-based opinion dynamics model on the frequency of activation of the links in this network. We then study and compare the networks generated with two different interaction process, namely central and peripheral processing, making vary some parameters of the opinion dynamics model.

Keywords: agent-based social simulation, social networks dynamics, opinion dynamics, attitude dynamics.

Paper presented at the ESSA conference, September 1-5, Brescia, Italy

1.Introduction

One of the key issues in social simulation deals with the formalization of social networks connecting agents and their dynamics. Originating from physics, the first models adopted the principle of "social atoms", where agents can interact with their adjacent neighbors in a Von Neumann or Moore neighborhood (see e.g., Goldenberg, Libai, Solomon, Jan, and Stauffer, 2000). As empirical evidence was overwhelming (see e.g. Milgram, 1967) that people not only have local links or strong ties, but also distant links or weak ties, Watts (1999) captured this principle in the small-world network, and demonstrated its impact on simulated social processes. Another observation was that people – and many other systems - may have a variant number of connections, which formulated as a power-law distribution resulted in scale-free networks, as introduced by Barabasi and Albert (1999). Realising that people have a limited capability of accepting new links, this approach was extended with the preferential attachment principle, as presented by Amaral, Scala, Barthemely and Stanley (2000). Also an aging principle of links was proposed by Dorogovtsev and Mendes (2000).

A key element in the development of simulated networks is the incorporation of behavioural assumptions in the network structure, be it principles of weak links, heterogeneity in number of contacts or preferential attachment. One essential process in the formation and breaking of links is related to opinion dynamics. People may be attracted to each other on the basis of similarity (e.g., Festinger, 1954), or, as stated by Lazarsfeld and Merton (1964), most human communication will occur between a source and a receiver who are alike (i.e., homophilous and have a common frame of reference). This homophily relates to congruency or similarity on attributes such as demographic variables, beliefs and values (e.g., Infante, Rancer & Womack, 1997). Focussing on attraction and rejection mechanisms in opinion dynamics (Jager and Amblard, 2004 ; 2007), we propose to use these opinion dynamics as the driving force that determines the frequency of interaction between agents (Jager & Amblard, 2008). Whereas previous approaches basically assume the presence or absence of a connection in binary terms, in this paper we propose a description of connection in terms of frequency of interaction. People and the networks they take part in are always changing, sometimes at a slow place, where once close contacts end in long lingering contacts. Basically the deletion of links as presented in several models does not exists, the frequency of interaction decreases but the link can be "re"-activated at any moment. Also contacts may suddenly emerge due to the discovery of a mutual interest, or end due to a conflict. Whereas in Jager and Amblard (2008) the focus was on studying the dynamics of the opinions resulting from this network formalisation, in this paper we want to report on the first steps in the identification of the network structures that emerge as a function of different tolerance levels in a population. More exactly we will focus on the condition of emergence of stable structures in the model. In the following section we will first explain the principles of the approach.

2.FreqNet: the model

A critical element in FreqNet is the rationale behind the interaction between people. Let's consider a population of n agents. In daily life the frequency on interaction is determined by a multitude of factors, such as (changes in) location, shared interests, family ties and many more. One key-driver identified in many psychological and behavioural studies is the similarity of people (Festinger, 1954). This similarity is based on several dimensions, e.g., work, sports, and politics. In our formalisation we start with 2 attitude dimensions: for a given agent j, A_j and B_j, ranging from -1 to 1. People may attach different importance to these attitudes. Hence agent j will weight the dimensions with a β_j value: $\beta_j * A_j$ and $(1 - \beta_j) * B_j$, considering that the total interest is equal to 1. Assuming the attitude position is easier to observe than the importance one attaches to it, we formalise agent j's perceived similarity with agent k as:

$$F_{jk} = \frac{(\beta_j + \beta_k)}{2} * |A_j - A_k| + \left(1 - \frac{(\beta_j + \beta_k)}{2}\right) * |B_j - B_k|$$

This parameter F_{jk} corresponds exactly in a first attempt, to the frequency of interaction of both agents, and is similar in the model as it is formalized now to a probability to discuss among agents j and k at each iteration. When agents contact they may discuss over attitude A and B. The chances of discussing over A depend on the relative importance of A, formalised as: $p_{discussA} = (\beta_j + \beta_k)/2$. As a result from the discussion the agents may change their opinions. For this we use the formalisation as introduced by (Jager and Amblard 2004; 2007). The key features of these models are that people sharing close positions (difference in attitude below the assimilation threshold) on a relevant opinion dimension are likely to become more similar (assimilation effects), whereas people really differing on a dimension (difference in attitude above the dissimilarity threshold) might become more dissimilar (contrast effects). Also a change on the dimension being discussed (central processing) will result in a change in a similar style (assimilation or contrast) on the other dimension (peripheral processing).

To sum up the basic principle, the opinions of connected agents as well as their relative importance are taken into account for updating these variables as well as to update the frequency of the link connecting them which in return influence the probability of interacting.

3.Experiments

In the experiments we focus on the type of network that emerges in terms of set of stabilized links (links having a frequency of 1, we could also name this structure the core network). In the actual paper we will present four single experimental runs to explain how the networks evolve as a function of attraction and repulsion dynamics. A more systematic study concerning the stabilization in the parameter space of the opinion dynamics model will be presented in the final paper. In the simulation runs we formalize 160 agents which discuss on 2 attitude dimensions. The attitudes of the agents on each dimension are initialized at random between -1 and 1. The relative importance of the first dimension compared to the other, β, is also drawn at random. The density of links is set at 0.05 (5%), the underlying network being drawn at random.

3.1. Experiment A: Acceptance Threshold 0,5 - Rejectance Threshold 1,5 - central processing only

The first condition we tested was with an acceptance threshold of 0.5, and a rejectance threshold of 1,5. The process behind this experience corresponds to a central processing, i.e. each dimensions are evaluated independently. In Figure 1 we present a screenshot of the emerging structure at convergence, we used for this a spring layout proposed by Netlogo and applied only to links having a frequency above 0.8 (other nodes moving according to the layout repulsion algorithm). Links are represented in grey color scale from white (frequency = 0) to black (frequency = 1). Only the attitude of the agents on the first dimension is represented here on a blue color scale, dark blue (black in fact) coding for -1 and light blue (white) coding for +1. As can be seen in the screenshot presented in Figure 1, several agents cluster linked by a high frequency network are overlapping at the centre, and a set of less frequent but far more numerous links stands in the background. Some rare agents that are not densely connected to the networks are pushed outside of the core structure. We have to notice also that the rate of stabilized links (i.e. having a frequency nearby 1) is above 20%.

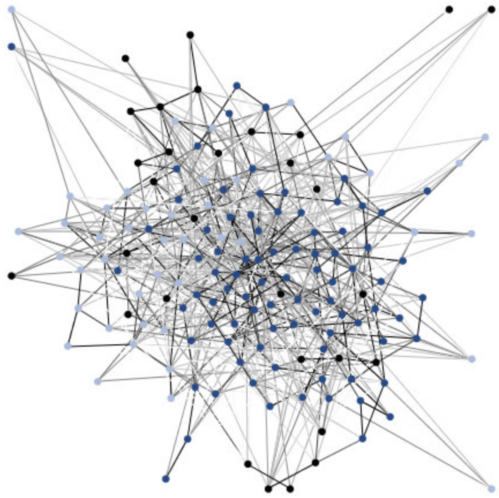

Figure 1: Screenshot showing the emerging network at convergence for experiment A (rate of links stabilized = 0.217)

The following figure 2 displays the evolution during the simulation of the distribution of the number of links depending on their frequency, this over 200 iterations of the model (this corresponds in this case to a convergence).

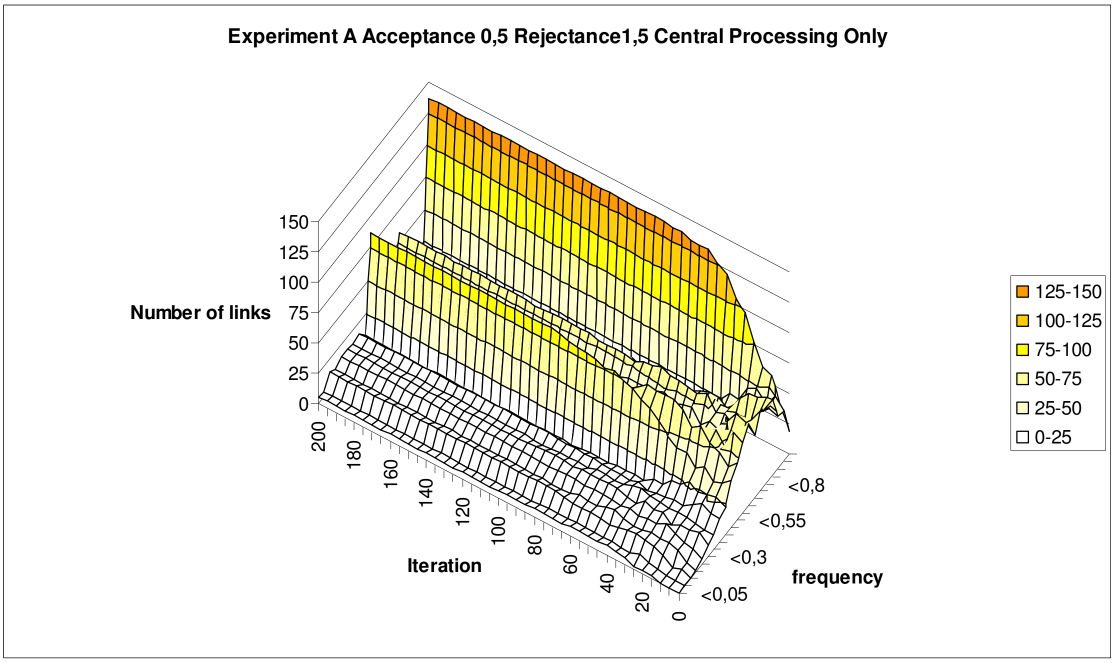

Figure 2: Evolution of frequency of interaction over time for experiment A a) random b) regular

Figure 2 shows the emergence of a significant core network composed by a set of links having frequency that is nearly 1. This core network regroups one fifth of all available links at convergence illustrating a case of important freezing of the social structure. Following the observation of figure 1, these highly frequent relations compose dense clusters regrouping agents sharing the same attitude rather than pair of agents homogeneously distributed over the network. Another important observation we have to mention concern two other significant values for the frequencies, a second cluster being identified from the distribution for frequencies equal to 0.5, regrouping 13% of the links and the other around frequency 0.75 regrouping a bit less than 10% of the links. Those two latter clusters correspond to less cohesive structures underlying the main core network. However, our conclusion from first explorations is that this less cohesive structure seems to play a crucial role in the interaction among the homogenous attitude clusters.

3.2. Experiment B: Acceptance threshold 0,25 – Rejectance threshold 1,75 - central processing only

The conditions of the next experiment was with an acceptance threshold of 0.25, and a rejectance threshold of 1.75. For this condition we observe quite a similar type of grouping as in the previous experiment, as can be seen in the screenshot in Figure 3. We identify again clusters of identical attitudes, but these clusters seems less cohesive as confirmed by the distribution of the figure 4. Moreover, at convergence, only 9,4% of the links obtain a frequency that approaches 1.0.

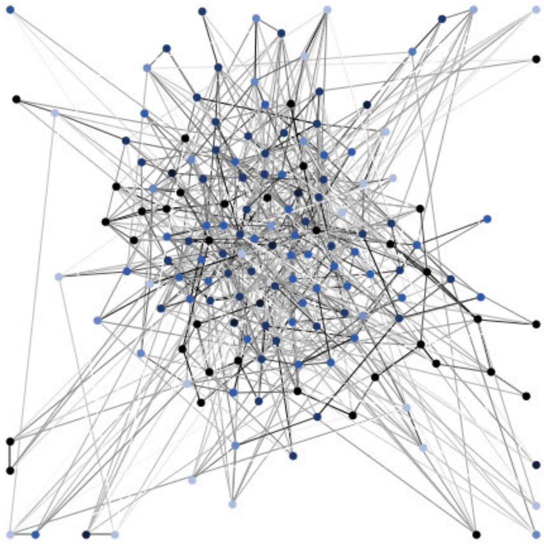

Figure 3: Screenshot showing attitude positions and links for experiment B (rate of links stabilized = 0.094)

Figure 4 displays the number of links arranged by the frequency of interaction.

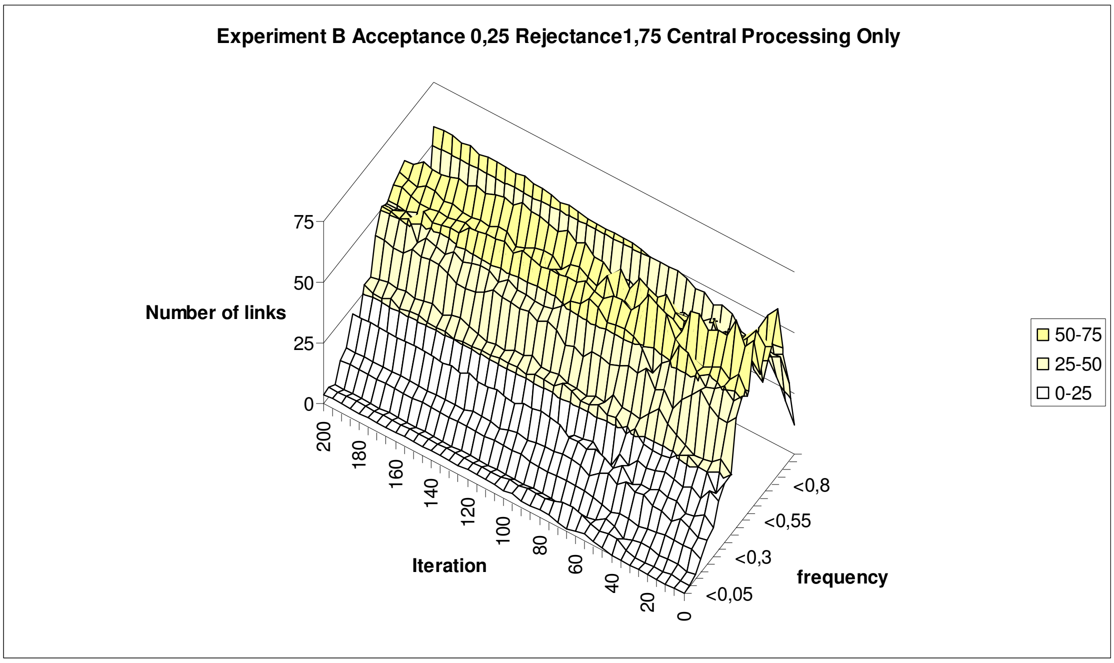

Figure 4: Evolution of frequency of interaction over time for experiment B

In Figure 4 we observe that the distribution of the links frequencies seems to be kept unchanged from the beginning. From the simulations run, it appears that the interaction regime is kept homogeneous without the emergence of "preferential interaction" among agents in the population.

3.3. Experiment C 3: Acceptance threshold 0,5 – Rejectance threshold 1,5 – both central & peripheral processing

Next we introduced peripheral processing. This implies that when agents interact on the most important attitude (on average for both of the interacting agents), the resulting shift will also be copied to the other attitude dimension (e.g. if radicalization occurs on the first dimension form central processing, there will be a radicalization on the other dimension whatever the opinions of the agents on this dimension, this is basically the principle of peripheral processing). In earlier experiments (Jager & Amblard, 2007) we observed for this condition that a very strong polarization emerged. Figure 5 shows the network resulting from this process.

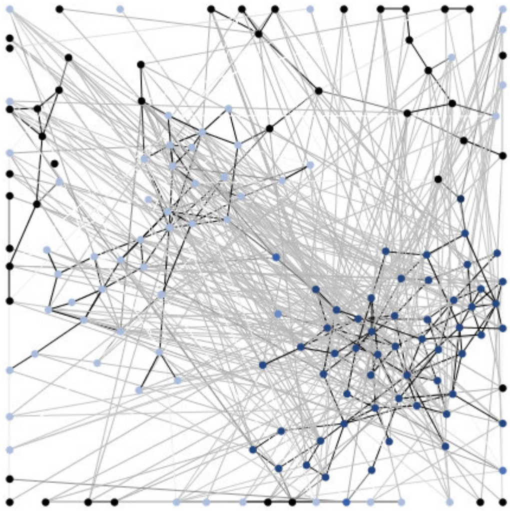

Figure 5: Screenshot showing attitude positions and links for experiment C (rate of links stabilized = 0.319)

From this figure, we clearly identify non-overlapping (at the difference from the preceding experiments) densely connected clusters. Figure 6 confirms this situation identifying clearly two clusters in the distribution of links frequency. Moreover, this dense clusters represent an important number of links as nearly 32% of the links have a frequency close to 1.

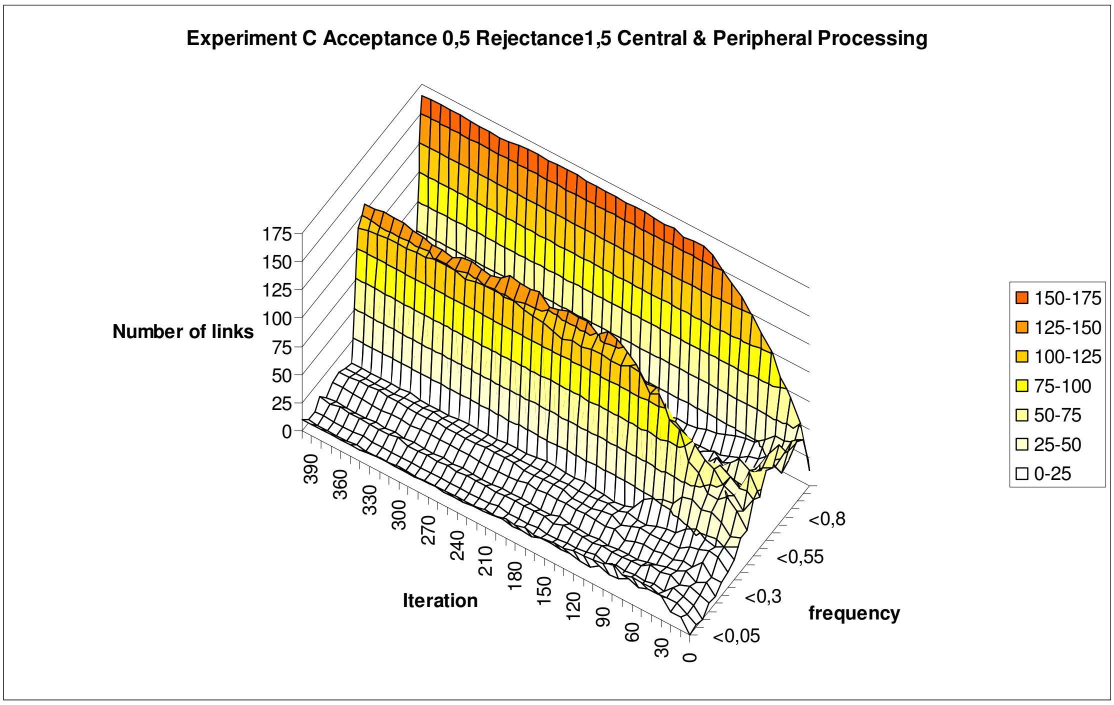

Figure 6: Evolution of frequency of interaction over time for experiment C

Concerning the figure 6 we renew the remarks we made on experiment A, which, at the exception of the peripheral processing, corresponds to the same parameters. That is, we observe again, apart of an important clusters of links for frequency around 1 (31%), another cluster for frequency around 0,5 that regroups 46% of the links. These links compose not only a substrate of links assuring the connection among cohesive homogeneous clusters as it appears that this set of less frequent links regroups agents sharing a similar opinion that is different from the one of the emerging strong network clusters.

3.4. Experiment D: Acceptance threshold 0,25 – Rejectance threshold 1,75 – both central & peripheral processing

Finally we tested the effects for peripheral processing under the condition of a large non-committment area. From (Jager & Amblard, 2007), in this condition we observe pluriformity with respect to the opinions. The situation here is far more similar to the one of the experiment B, sharing the same parameter values, if not the same interaction process.

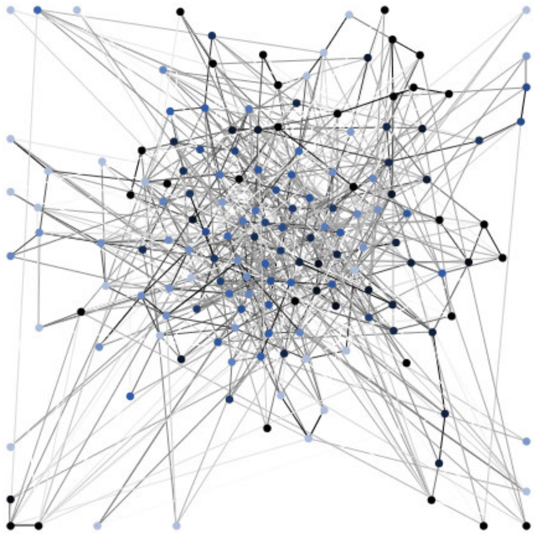

Figure 7: Screenshot showing attitude positions and links for experiment D (rate of links stabilized = 0.075)

Figure 8 displays the number of links arranged by the frequency of interaction, which corresponds also to the experiment B.

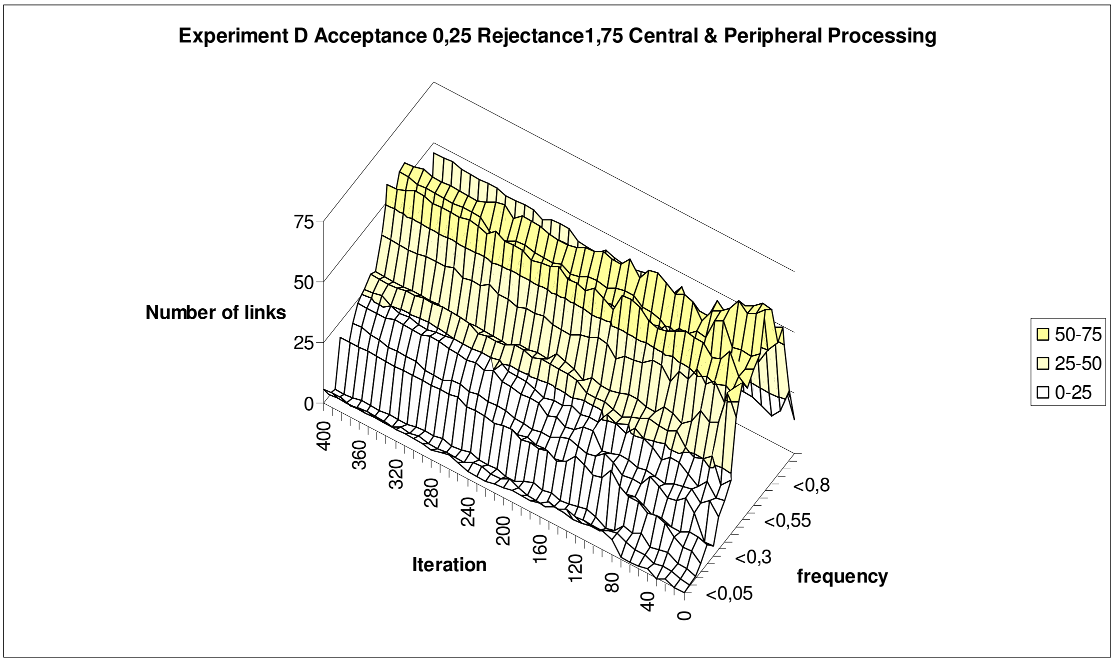

Figure 8: Evolution of frequency of interaction over time for experiment D

4.Discussion

It is obvious that the experiments presented in this paper are just a first step towards a more systematic exploration, and that the experimental results presented in this paper are merely a first indication of the potential results of using FreqNet. However, we think that the proposed model is very interesting as already some phenomena of interest become visible. For example, we observe that attitudinal processes have a serious impact on the resulting network characteristics, and that subgroups of agents emerge having different types of networks. As in the literature it is also known that certain groups of people have different types of networks than other people, e.g. innovators and early adopters in the innovation diffusion process

(see e.g. Rogers, 2003), these first results are promising with respect to the capability of capturing real world social network characteristics. However, much work has to be done to present a systematic perspective on how attitudinal change and opinion dynamics interfere with network shapes and dynamics.
If accepted we will include a systematic exploration of the part of links taking part in the core structure in the parameter space of the model. Even incomplete (as it won't bring anything about how these links are connected to each others), such a study will enable us to identify the zones of the parameter space that leads to more cohesive or on the contrary more egalitarian (concerning modestly the frequency of links) networks.
Further work will involve large series of experiments, where we will vary the characteristics of the population and measure network properties. Typical variations of population characteristics are the formalization of different distributions of acceptance and rejectance boundaries, the respective force of acceptance and rejectance mechanisms, the susceptibility to change, possibly in relation to issues of power and reputation, which in its turn may be related to the network position. Ultimately this may result in the exploration of trajectories leading towards the emergence of opinion leaders and followers. This approach will result in a perspective on how agent characteristics may relate to the (chance of) position in the network. With respect to measurements of the network properties we propose to measure centrality and connectivity of interactions for moving time-slots as to express the network characteristics over time. Possibly these indicators can be linked to types of agents, which may reveal the typical networks of different types of agents.

We expect however that letting agents shape their own networks on the basis of behavioral processes – rather than imposing a static network on them – may result in an interesting venue for the study of the emergence and dynamics of social networks, which may be relevant in many contexts.

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