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Dynamics of structured attitudes and opinions

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Abstract

Opinion dynamic models frequently assume an opinion to be a one-dimensional concept and only sometimes vectors of opinions are considered. Contrary, psychological attitude theory considers an attitude to be a multidimensional concept, where each dimension is composed of beliefs and evaluative components. In this article we extend classic basic models of opinion dynamics such that they can capture this multidimensionality. We present models where individuals talk about different issues, e.g. evaluations or beliefs about the relation between objects and attributes. We present reinterpretations the results of previous simulations and we present results of simulations of new dynamics. Those new dynamics are based on a hierarchical approach to bounded confidence.

1 Introduction

The understanding of processes that drive opinion formation in groups of individuals can support many different applications. For example, it can improve predictions of consumer behaviour or of voting behaviour, and it can enable more precise planning of marketing communication strategies. It can also support the governmental planning of policies and their adoption. There are many models that describe and explore such processes. Opinion dynamic (OD) models as introduced by Nowak et al. [13], Hegselmann and Krause [10], Deffuant et al. [7], and others are some of the most simple approaches; but they allow for a clear analysis and understanding of the fundamental dynamics. From my point of view taking these models as starting point and *increasing complexity step by step* enables us to keep track of the sources of complexity and of specific dynamics.

Most models of opinion dynamics consider an individual's opinion[1] as a one-dimensional value, either binary as good and bad opinion, or with a finite

[1] According to Trommsdorff [14] *opinions* are *verbalized or expressed attitudes*, while *attitudes* are mental states of individuals. This was introduced into models of opinion dynamics by Urbig [15]. Because we are not concerned with biases of the attitude–opinion relation we use the terms opinion and attitude as synonyms here.

number of stages between the extremes, or as a continuum between extreme values [10, 16]. Sometimes such models also include uncertainty about the opinion (see for example [5]). These one-dimensional approaches to opinions and attitudes may be beneficial for understanding basic dynamics, but it is questionable whether they can capture the complex dynamics displayed by opinion dynamics in real settings, e.g. the diffusion of innovative products or complex programs of political parties. In consumer theory more complex models of individuals are applied; a consumer is described by *cognitive processes* and *activating processes* [11]. The first type of processes is concerned with information processing while the second type directly drives the behaviour of an individual. These two sides of behaviour are very interesting and they also appear in other contexts; e.g. a similar distinction can be found in agent theory developed in computer science. Wooldridge and Jennings distinguish between *pro-attitudes* and *information-attitudes* as classes of agent states [17]. Pro-attitudes drive the behaviour of an agent while information-attitudes influence the cognitive processes. According to Wooldridge and Jennings one needs at least one element from both classes to model *intelligent agents*. These arguments are at a very general level, but by considering psychological attitude theory a one-dimensional approach seems to be inappropriate, too. An attitude is composed of different *impressions* that themselves are composed of two elements: *cognitions* or *beliefs* about the presence of some attributes and *evaluations* of these attributes [1]. This is the same distinction as introduced above, but it additionally emphasizes a multi-dimensionality of the attitude construct. Furthermore, such multi-dimensional models are at the core of most of the reliable approaches to attitude measurement [3]. Measuring attitudes gets important when linking simulations to real data. Multidimensionality and the distinction between evaluations and cognitions seem to be very general though relevant concepts.

There are some attempts to include multi-dimensionality into models of opinion dynamics. But unfortunately the multi-dimensionality is then interpreted as a set of opinions instead of several elements of the same opinion or attitude. In this article we want to incrementally develop a model of dynamics of structured attitudes that gets closer to psychological attitude theory, i.e. to the model of Fishbein and Ajzen [1]. We will include multi-dimensionality as well as the distinction between beliefs about the strength of attributes regarding an object and evaluations of these attributes. For our explorative study we first start with multi-dimensional models of opinion dynamics and re-interpret them in front of multi-dimensional attitude theory. In our models, agents communicate about different attributes of an object, e.g. the price or quality of a product or the medical or national defence aspects of a political program. Additionally they can discuss their beliefs or their evaluations regarding these attributes. We then extend these models to capture more aspects that may affect the dynamics of structured attitudes. For instance, differences in the overall attitude towards an object may raise selective attention or bounded confidence towards other agents, while differences in beliefs can be seen as informative. We will present different possible approaches. This article should initiate a discussion whether and how such extensions directed at more sophisticated attitude theory can be beneficial from a modelling or empirical perspective.

1.1 Attitudes as a more-dimensional concept

An attitude is a summary evaluation of a psychological object. It is composed of beliefs that associate the object with some attributes, i.e. cognitions, and evaluations of these attributes [2]. An attribute evaluated with respect to some object is defined as an impressions related to the object. Based on the expectancy-value model of attitude an attitude A is positively correlated to the sum of impressions related to the focal object, while impressions are given by products of evaluation a_i of an attribute i and cognition c_i representing the beliefs about the association of attribute i to the focal object [4].

1.2 Multi-dimensional Opinion Dynamics

As already mentioned many models of opinion dynamics only consider one-dimensional opinions and only a few authors have investigated dynamics of vectors of opinions and have developed different interpretations. Deffuant et al. and Weisbuch et al. consider a vector of binary values as a set of opinions towards different objects [7, 16]. Lorenz investigates a model of n-dimensional vectors of real values, where the real values represent the amount of money allocated to n projects [12]. In Lorenz's model agents interact and adapt their opinions if the Euclidian distance of these opinions is smaller than a constant. Thereby he extends the concept of Bounded confidence by Hegselmann and Krause [10] from one-dimensional opinions to vectors of opinions. The same is done by Fortunato et al. [9]. In other multi-dimensional models the vector represents a culture and every element of the vector is a specific element of the culture, e.g. Axelrod [6]. Cultures converge if they do not differ in a sufficient number of elements. All together, there are different interpretations of vectors of opinions, but as far as we know there is no interpretation that refers to structured attitudes or opinions. We will now reinterpret those dynamics of vectors of opinions in front of our simple attitude model presented above. Thereby we focus on vectors of real numbers between zero and one and on the bounded confidence model of Hegselmann and Krause [10]. The communication regime is dyadic, i.e. in every step two randomly selected agents interact, and is therefore the regime as applied by Deffuant et al. [8].

2 Reinterpreting multi-dimensional OD

We model an attitude as given by (1). The normalization of cognitions is just for making analysis easier, but the model can also be developed without this normalization[2].

$$A = \sum_{i=1}^{m} im_i = \sum_{i=1}^{m} c_i \cdot a_i \quad \text{with} \quad \sum_{i=1}^{m} c_i = 1 \quad \text{and} \quad 0 \geq c_i, a_i \geq 1 \tag{1}$$

In the context of this simple model of attitudes there are different possible interpretations of vectors of real numbers. They can either represent impressions im_i, while agents in the model mutually affect their impressions. Considering impressions as being composed of cognitions and evaluation, then given a constant set of cognitions c_i about the presence of some attributes, a vector of real numbers can represent a vector of evaluations a_i of attributes. In this case, agents communicate about their evaluations and these interactions may change the way agents evaluate the attributes. If all cognitions are the same then the second approach degenerates to the one related to impressions only. A third way to interpret vectors of real values in the context of attitude theory is to see them as vectors of cognitions c_i that link attributes with the focal object. Following this view, agents exchange information about how strongly attributes are related to an object. Mathematically these three interpretations are very closely related and are either special cases of each other or are from a modelling perspective the same apart of re-labelling variables. A slightly different approach is if individuals can talk about evaluations as well as about their cognitions, then the evolving vector of real numbers contains elements related to c_i and a_i, which finally causes a different dynamic of the overall attitude A. However, typical for all four interpretations is the fact that agents talk about elements of their attitude but the attitude itself is a function of these elements and itself does not affect the dynamics.

Before we start reinterpreting the dynamics we briefly characterize the initial conditions. As usual in OD models we consider a flat distribution of opinions within the multi-dimensional opinion space, i.e. among all a_i. Depending on the number of dimensions and values of fixed parts of the model, e.g. cognitions or evaluations, the distribution of A is different. Figure 1 visualizes this effect. For one attribute the distribution of A is flat. For two attributes, i.e. two dimensions, the distribution depends on the cognitions. If both attributes are associated with the same strength to the focal object, i.e. $c_1 = c_2 = \frac{1}{2}$, then a triangular distribution of A is implied. If one attribute is irrelevant, i.e. $c_1 = 0$ then the model reduces to a one-dimensional one and thus A has a flat distribution. If c_1 is in between then A follows a trapezoid distribution with a height depending on c_1. For three attributes with no irrelevant attribute the distribution is similar to a normal distribution. Altogether one can see that the more dimensions we consider and the more they are equally weighted, the less extremists related to the overall attitude A are present in the initial state.

[2]Without normalization communication gets more difficult and we must include assumptions about what people mean by an attitude of 0.1 or 2, because the interpretation of these values then depends on the number of attributes.

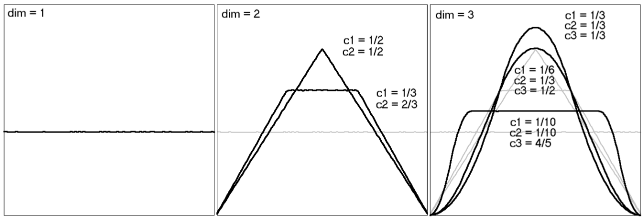

Figure 1: Initial attitude profiles for different cognitions and dimensionality

Communicating about evaluations For the attitude model in (1) we now fix components c_i and let agents talk about a_i's. Basically we get the typical multi-dimensional opinion dynamics. For visualizing the long-term distribution of the overall attitude A we plot the iso-attitude lines, i.e. areas of the same overall attitude, and derive the distribution of A (see Figure 2).

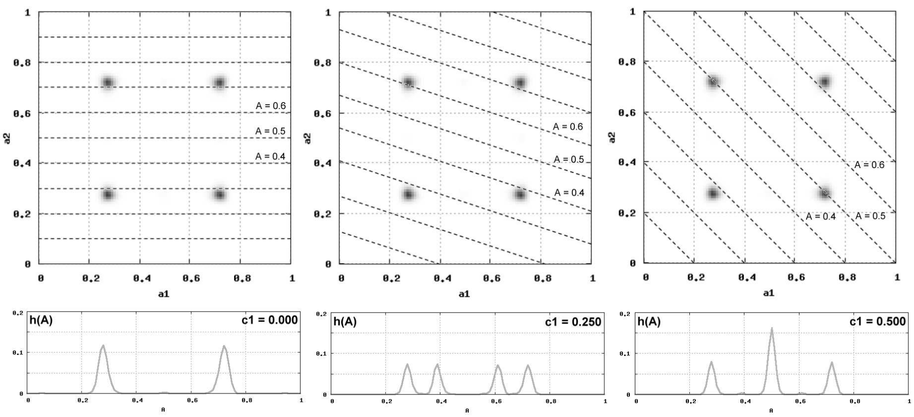

Figure 2: MDOD with flexible a_i but fixed c_i: (a) $\frac{c_1}{c_2} = 0$, (b) $\frac{c_1}{c_2} = \frac{1}{3}$, (c) $\frac{c_1}{c_2} = 1$

For equally weighted attributes (right hand part in Figure 2) we learn that people with extreme overall attitudes are mostly similar or even identical in their beliefs about and attitudes towards attributes of the object, while people with intermediate overall attitudes may differ significantly in their evaluations. These intermediate individuals may agree on an overall level but they disagree at the level of single attributes. The latter are in areas with asymmetric evaluations, i.e. the value one attribute high and the other low. Individuals with extreme attitudes either value all attributes high or all low, i.e. we label these individuals with symmetric evaluations. Since the major clusters regarding the attributes tend to be of the same size, the clusters regarding the overall attitude differ in their size. Intermediate clusters are significantly bigger than the more extreme clusters. From this we can see that the more dimensions are considered or, in other words, the more detailed an object is evaluated the less likely extremists or the smaller their groups become, but this effect is basically caused by the shape of the initial attitude distribution. The more asymmetric the cognitions are, the weaker this tendency. If one attribute is irrelevant at all, then also extremists that agree at the attitude level may disagree at the attribute level for the irrelevant attribute (left hand part of Figure 2). Traditional OD models can represent the dynamics at the attitude level. With one more and one less relevant attribute we see that at the attitude level two clusters may survive that are located closely to each other. A one-dimensional OD model cannot explain such configurations.

Communicating about evaluations and cognitions Agents may not only talk about evaluations or only about cognitions. Both types of communication may be combined, such that agents collect knowledge about the attributes of an object but at the same time they are influenced by others how to evaluate these attributes. Due to the normalization of the cognitions we need at least two dimensions to allow for flexible cognitions. If agents can talk about a_i as well as c_i then we get a three-dimensional dynamic. For a better visualization we hold the evaluation for the second dimension constant and allow for a communication about a_1 and c_1. The iso-attitude lines change in their shape. Figure 3 displays the results for three settings. We can see that this reinterpretation of multidimensional OD explains a different class of attitude configurations with number of clusters in A depending on the fixed evaluation a_2.

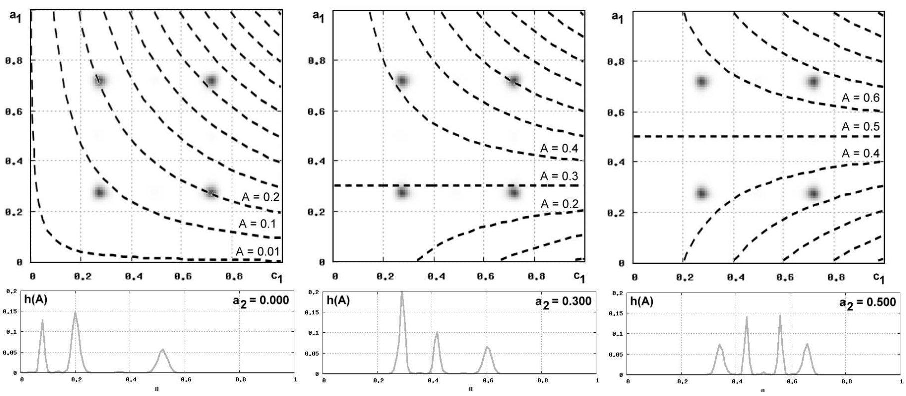

Figure 3: Flexible a_1, c_1 but fixed a_2: (a) $a_2 = 0$, (b) $a_2 = 0.3$, (c) $a_2 = 0.5$

3 Hierarchical bounded confidence

Until now we have referred to dynamics that are identical to previous models, especially to models of bounded confidence, where agents compromise if they are not too far away in the space of their relevant issues. What does bounded confidence mean in a world of structured attitudes? In fact, we have two levels, i.e. the attitude A and the attributes i with their evaluations a_i. Bounded confidence can be applied to both levels, such that individuals agree on an attribute if they do not differ too much at the overall level, and if they do not differ too much at the attribute level, then they discuss specific attributes of the object. This approach is perhaps less suitable for simple objects but for political program of parties it may be a reasonable approach to consider that only aspects are discussed in a conversation instead of the whole program. But if people join such a conversation they should not differ too much at their overall attitude towards the party under consideration. For modelling this we introduce two parameters describing the maximal deviation at both levels, i.e. ϵ_A for the overall level and ϵ_{ai} for the attribute level. Two extremes can be generated, i.e. $\epsilon_A = \infty$ and $\epsilon_{ai} = \infty$. Figure 4 visualizes the basic effects for these cases. In the first case cognitions do not affect the dynamics as in the simple models before and each dimension in the attribute space displays a dynamic that is the same as in one-dimensional models. The second case reduces to a one-dimensional dynamic along the overall attitude. However, due to the initial distribution (see above) a stronger tendency to consensus can be seen even for more narrow-minded individuals.

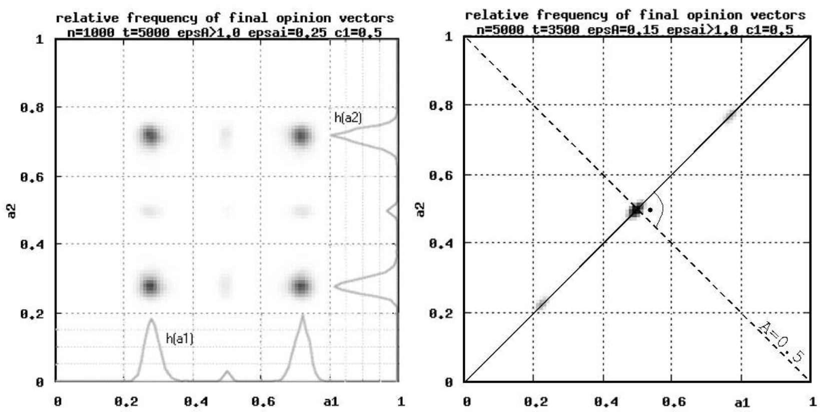

Figure 4: Two special cases for the hierarchical bounded confidence model

We consider bounded confidence for attribute evaluations to be bigger than for the overall attitude, i.e. regarding the attributes they are more open-minded. This open-mindedness may stem from the fact that the impact of a single attribute is not that big, which means that the individual may be more open to changes. Simulations will show how this two-level Bounded confidence changes the distribution of clusters at the level of single attributes but also at the level of the overall attitude.

Figure 6 visualizes simulation results[3]. In a column we step-wise increase

[3]The right hand case in the second row shows that sometimes the three clusters on the left or right collapse into two clusters.

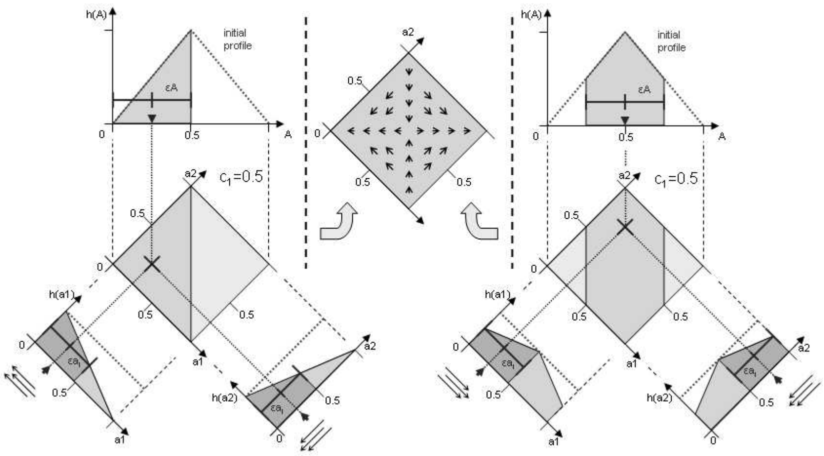

Figure 5: Visualization of the mechanism that leads to the depletion of the areas with asymmetric attribute evaluations

the cognition for attribute one, i.e. from irrelevant to equally weighted with attribute two. We see that the more equally they are weighted, the less cluster appear in areas with asymmetric evaluations. The effect of more central initial opinion profiles for more than one equally weighted dimensions seems to be counter-balanced by the processes involved in our hierarchical bounded confidence model on structured attitude dynamics. The reasons can be identified in Figure 5, which shows the dynamics for the case in the lower left corner of Figure 6. For settings with $c_1 > 0$ this effect is strengthened by increasing the narrow-mindedness at the attitude level, which is done in every row, where both attributes are relevant. The tendency to move from asymmetric evaluation to the centre becomes less if cognitions get more asymmetric.

4 Conclusion and future work

This paper presented a first explorative study for modelling attitudes as being a multidimensional concept where each dimension is composed of a beliefs about associations of attributes with the focal object and evaluations of these attributes. We reinterpreted classic opinion dynamics and thereby considered that the overall attitude does not affect the dynamics. In a second step we considered a hierarchical bounded confidence model, where the overall attitude affects the dynamics. Simulations have shown that final attitude configurations may differ strongly from the configurations explained by one-dimensional models. However, the dynamics get relatively complex and it is an open question whether such models can contribute to understanding complex opinion dynamics.

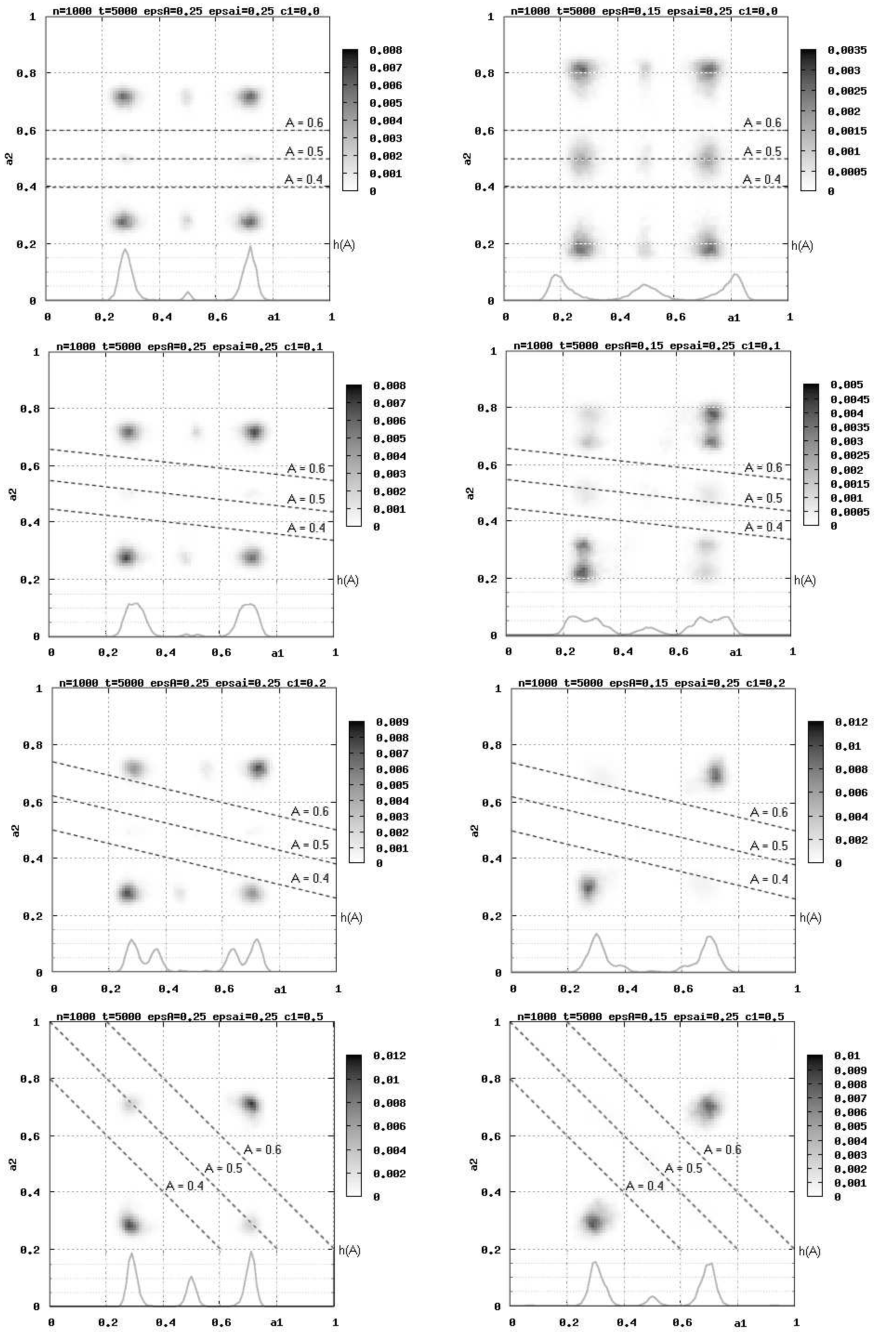

Figure 6: Hierarchical bounded confidence for different cognitions and two levels for bounded confidence at the attitude level: relative frequency of attribute evaluations (a_1,a_2) und attitude A

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