

Modeling the Influence of Multiple Social Groups on Agents Behavior

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Abstract. The behavior of agents is not only influenced by other individual agents, but also by the overall behavior of groups of agents. Since group behaviors are the aggregation of individual behaviours, they are mostly neglected in agents' decision making process mainly because in agent-based models, the focus is on interactions and individuals behaviors rather than global patterns. In this paper we explain how group behaviors can be considered in agent-based models, and how the agents can use such behaviors in their decision making process.

1 Introduction

When faced with a decision (e.g. buying a new car) many people seek the opinion of others in order to support their decision. This is specially true, when people are not certain about their choices and options due to lack of information. Besides seeking the support of their peers and close relations, people are also influenced by the choices made by reference groups (e.g. celebrities, or experts). Social entities however, are not only influenced by direct contact with other entities, they are also affected by their own perception of the global trends whether in the society as a whole, or within their own local groups.

In agent-based models, the agents and their interaction determine the behavior of the system [4]. However, perceiving the global situation in a simulation is not the task of the agents in the simulation. Therefore, since the data is not available to the agents, they cannot take the over all perceptions into account while making decision about their activities. This limitation is partly due to the bottom-up nature of this simulation approach, but also related to the fact that it is difficult to capture run-time behavioral patterns in the simulation and allow the agents to take them into account in their subsequent decisions.

To overcome this problem, modelers take various approaches. For example, [18] implement agents that adopt identical average social strategies. In reality, however, agents are influenced differently by common behaviors based their own characteristics.

Furthermore, besides the aggregate behavior of the society, the agents are also influenced by the various groups they belong to, ranging from their families, to the work environment or even their neighborhood. The local aggregate behaviors

in these groups may even be conflicting. Therefore, depending on which group has more priority, the agent behaves differently. [16,17] address this issue by defining neighborhoods and assigning average strategies as the overall behavior of each neighborhood.

Given the current state of art, the challenge still lies in the computational representation of aggregate behaviors, the way they would be perceived by the agents and the way these perceptions would be incorporated into the decision making process of the agents. The problem becomes even more challenging when we see that there are multiple groups, even with conflicting aggregate values, all being taken into account by individuals.

In order to represent aggregate values belonging to groups of agents in a simulation we present a framework for agent decision making where agents are exposed to different options for performing a behavior. The number of agents performing each option in every group the agent belongs to, influences the decision of that agent. Inspiring from TRA (Theory of reasoned Action) [1], we use the concept of intention that would lead to behavior in agents. Attitude toward a behavior and social pressure are the factors that influence intention. To illustrate how this framework can be applied, we use an example case of consumer lighting.

The structure of this paper is as follows. In Section 2, we present the concepts that we will be using to define our proposing method. In section 3 we explain our proposed method. In Section 4, we will explain a working example based on our proposed method. In Section 5 we will finish with some discussion and concluding remarks.

2 Background

In order to find out how the aggregate behaviors of a system influence agent decision making, we need to (1) formalize how agents' decision is influenced by external factors, and (2) select a method for decision making that consider the aggregated behaviors of systems as a variable in the decision making process of individuals in addition to other factors that influence the decision.

The literature on opinion dynamics can helps us explain how the agents are influenced by external factors. Besides, for explaining the decision making process of the agents, we will use the theory of Reasoned Action.

2.1 Opinion Dynamics

[8] and [14] present two well cited continuous opinion dynamics models. In the first one, Deffuant and his colleagues present a model in which an agent readjusts his opinion with other agents when the differences between his opinion and one of his neighbors opinion is smaller than a threshold. In the second model, Hegselmann and his colleagues develop a model in which, in every iteration, agents take into account the opinion of all neighbors instead of one agent. None of these models consider the effect of group opinion as a whole on the formation

of agents opinion. Since continuous opinion dynamics models see communication between agents as the source of changes of opinion [26], they propose that opinion of agents change through the individual communication with other agents. Therefore, they do not consider the effect of groups opinion or opinion at the macro level of system (society) on the behavior of agents.

Among the discrete opinion dynamics models that have received more attention such as Ising model[12], voter model [15], majority rule [11], Social impact theory [20], and Sznaid model [24], only [11] consider the effect of group opinion on the opinion formation of agents. [11] present a model in which agents take the opinion of majority instead of modifying their opinion through the individual interaction. However, [11] present the effect of group opinion in a linear way. For instance, there is no difference between the effect of a group with 99 percent similarity and a group with 51 percent on the formation of an agents' opinion.

2.2 The effect of group behavior on individuals

Social pressure is the influence of groups' behavior that encourages an agent to change his behaviors to follow the group norms. First attempts to study the effect of groups behavior on individuals behavior have been done by Asch [3] and Sherif [23] where people were found to follow the rest of group opinion. [3] called this phenomena social pressure. [6] describe social pressure (conformity) as the act of changing one's behavior to group norms.

[2] explain that in many situations where individuals are uncertain how to act or think, they refer to the behavior of others to figure out what is going on in the situation and what is right to do. [9] argue that 'Informational social influence' is a psychological phenomena where people follow the action of other people in order to do the correct action. [2] argue that "Informational social influence" occurs when individuals see other people as a source of information.

Besides the informational social influence, the "normative social influence" is the second psychological phenomena that social psychologist defined as the source of conformity. Normative social influence is conformity in order to be liked and accepted by others [9].

Individuals don't always follow the behavior of groups. In the following situations the effect of social pressure is more powerful than normal situation [2]:

- **Ambiguous situation** Ambiguity is the most crucial parameter that increases intention of people to follow others behavior.
- **Crisis situation** In the case of Crisis situation as people do not have time to evaluate multiple option they will look at other people actions.
- **When Other People Are Experts** When people are not expert in a topic they will follow experts.
- **When People are Member of a Group** Self-categorization theory [25] explains that individuals are more likely to follow the group behavior when they perceive collections of people (including themselves) as a group.

In the next section we will classify the influential parameters of social pressure and explain how social pressure along with internal attitude determine the

behavior of agents in a society. In order to do that we use the theory of reasoned action (TRA).

Theory of reasoned action [1] is an attitude-behavior theory. It explains that when a person has the intention to do an action, he/she should be in favor of doing it (attitude). Furthermore, the person may feel social pressure to do the action (subjective norm). Attitude and norm will shape the intention of individuals towards a behavior. Figure 1 presents the conceptual framework of TRA.

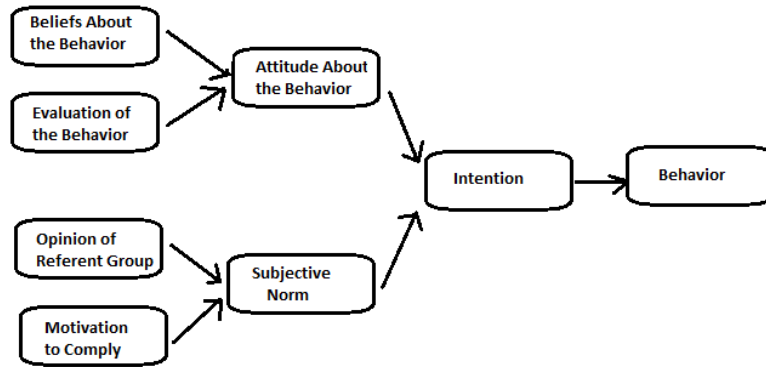


Fig. 1. The theory of reasoned action [1].

3 Modeling the Effect of Multiple Social Groups

Inspired by TRA, in this section we propose a framework for decision making process of agents which follows the idea that the behavior of agents is the consequence of their decision making process which is influenced by two parameters: social pressure and attitude towards the alternative options of a behavior. The framework classifies multiple parameters which influence the formation of attitude and the power of social pressure on the behavior of agents. As it is depicted in Figure 2 decision making of agents are influenced by the attitude and social pressure from multiple groups towards the multiple option of a behavior.

In the following, we explain every part of the model and their relationship in details based on social psychology literature.

3.1 Attitude

Attitude towards a behavior is individual's positive or negative feelings about performing that behavior. When agents have multiple option to choose from, they will evaluate different attributes of every option and perform one with

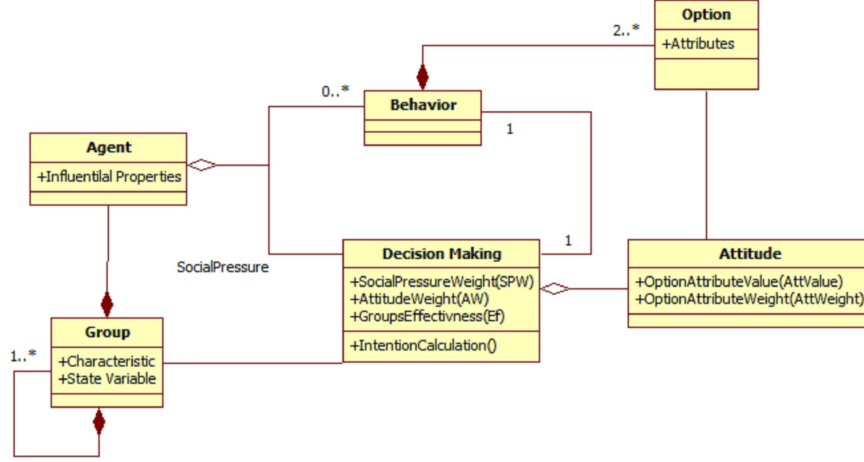


Fig. 2. Agent decision making with group influence

higher advantage and lower disadvantage. In reality, individuals do not give same weight to the different attributes of options. For instance, while a person may see an attribute of an option as an advantage, it may be seen as a disadvantage by another person.

Let n be the number of attributes of option j that agent i will be faced to perform one action. $AttValue_1$ and $AttWeight_1$ are value and weight of $Attribute_1$ from the point of view of agent i . A_i is the attitude of agent i towards option j .

$$A_i^j = \sum_{x=1}^n AttValue_x^j * AttWeight_x^j \quad (1)$$

The value and weight that agents give to the different attributes of an option change due to interaction and communication between agents. During communication agents share their information and experiences which result in changes in the value and weight given to options. Consequently, the attitude of agents towards different options change.

3.2 Social Pressure

Social pressure is the influence of groups' behavior that encourages an agent to change his/her behaviors to follow the group norms.

Norm refers to what is commonly done (what is normal) or to what is commonly approved (what is socially sanctioned). Despite the common label, these norms have different effects on the behavior of individuals. [7] point out that "Descriptive norm" refers to what people do and "injunctive norm" refers to

what people approve. [21] argue that **descriptive norm information** in a society influences the behavior of people.

We use the descriptive norm information (information about the number of people who perform a behavior) as the main parameter that shapes social pressure towards a behavior. Since in reality we are influenced by different groups, characteristics of each group is an important parameter which determines the power of social pressure. Furthermore, some agents are more influenced by social pressure due to their own internal characteristics which has to be taken into account when calculating the power of social pressure.

In the following, we present group characteristics and internal properties of agents which influence the power of social pressure.

Agent properties Since in society not every one conforms to social pressure some researchers study the effect of different factors that affect the tendency of individual to conform with society. In our proposed framework we call these kind of factors “Influential Properties” of agents. As an example of such properties, people who belong to individualistic cultures, such as American and British cultures, are more likely to behave independently than those from collectivist cultures such as China and Japan [5]. In collectivist cultures, group decision making is highly valued, while in individualistic cultures people are more concerned with their independent success than the well-being of their community. Besides the culture, gender and age also influence the tendency of people to conform with groups [10]. Women and younger people are more likely to follow the group’s behavior than men and older people. Influential Properties of agents determine to what extent agents stick to their own attitude or be influenced by the social pressure.

Group Characteristic and states Individuals are influenced by two kinds of groups in their decision makings. Those that they belong to and have direct connection with (e.g, family, colleagues, neighbors) and those groups that the agents don’t belong to, but indirectly influence their behavior (e.g, movie stars, political groups). Although, the effect of both kinds of groups (direct, indirect) on the behavior of agents is almost the same, for more clarity, we formulate the effects of them separately. Every group has different level of influence on the behavior of individuals which is dependent on the characteristics of that group:

- **Unanimity** when the behavior of the rest of the group is unanimous, individuals are more likely to follow the group behavior.
- **Cohesion** groups with high cohesion result in more conformity of individuals.
- **Status** individuals are more interested to follow high status groups.

In the case of direct groups, as agents have more information about the characteristics of the group and the choice of other group members, all the mentioned characteristics hold and thus make direct groups more influential. In Formula 2, DEF_k^i presents the effectiveness of direct group k on the behavior of agent i .

Let m be the number of direct-groups which surround agent i . The direct social pressure (DSP) that forces agent i to choose option j is determined by Formula 2. In every group the number of agents which have chosen option j is multiplied by the effectiveness of this group from the point of view of agent i determines the social pressure of that group towards option j . Summation of every group pressure towards option j on agent i calculates DSP_i^j .

$$DSP_i^j = \sum_{k=1}^m DEF_k^i * (N_k^j/N_k) \quad (2)$$

In the case of indirect-groups, the effects of these groups is mostly due to imitation of agents from these groups. The status of groups and the average number of groups members which adapt a option are most important parameters which shape the effect of these groups towards an option.

Let T be the number of indirect-groups which influence agent i . The indirect social pressure (IDSP) that encourage agent i to choose option j is determined by Formula 3. The average number of agents which have chosen option j is multiplied by the importance of a group from the point of view of agent i determines the social pressure of that group towards option j . $IDEf_k^i$ is the effectiveness of indirect-group k on the behavior of agent i . Summation of every group pressure towards option j on agent i calculates $IDSP_i^j$.

$$IDSP_i^j = \sum_{k=1}^T IDEf_k^i * (Ave_k^j) \quad (3)$$

Besides the two mentioned groups that influence agents opinion, the opinion of agents may be influenced by individual interaction. Every individual can be assumed as a group with one member. Therefore, the only parameter that influences an individual is the status that this individual has from the point of view of the agent.

3.3 Decision Making

Although TRA is aimed to study the intention of people towards a behavior, it can be applied to situations where people have multiple choices [22]. Individuals form intentions towards each alternative based on their attitude and subjective norm towards that alternative. The alternatives will be compared and the alternative with the strongest intention will be selected.

In our proposed framework, we assume that every agent has multiple choices to perform (e.g., voting for group A or group B, Buying LED lamp or incandescent lamp). Agents will form their intention towards each alternative based on their attitude and social pressure. They will then compare the strength of their intentions towards each of the alternatives and will choose and perform the alternative with the strongest intention.

Intention of agent i towards option j is determined by Formula 4. **Attitude Weight** (AW) and **Direct Social pressure Weight** (DSPW) and **Indirect Social pressure Weight** (IDSPW) determine how much an agent follows his or her attitude or is influenced by social pressure of direct-groups and indirect-groups. We already mentioned that **Influential Properties** of an agent and the situation that an agent is in (e.g, ambiguity and crises) influences the amount of “Attitude Weight” and “Social pressure Weight”.

$$I_i^j = AW * A_i^j + DSPW * DSP_i^j + IDSPW * IDSP_i^j \quad (4)$$

4 Working Example: Consumer Lighting Choices

As an example, we take a consumer lighting case to explain our approach for modeling the effect of group behavior on the decision making of agents. This example is chosen because of the high level of uncertainty in choosing between different kinds of lamps specially because of the emerging technologies in the market.

Case description Developments in electric lighting technology have increased the life time of the bulbs and their energy efficiency [13]. For example, over 98% of the electricity used in the traditional incandescent bulbs is converted into heat and not into light. However, Compact Fluorescent Lamp (CFL) or Light-Emitting Diode (LED) are nowadays the more efficient alternative lighting products. Nonetheless, consumers have only partially adopted CFL and LED technology because of a number of obstacles [19]. First, CFL and modern LED saving lamp are characterized by high up-front costs for consumers and poor light quality. Second, halogen lamp are more attractive than CFL and LED lamps because they fit in popular designs and have favorable color and size.

Model Specification We model the changes in behavior of 2000 agent towards three options (buying Light Emitting Diode (LED) lamps, Compact Fluorescent Lamp (CFL) lamps, and traditional incandescent lamps). Attitude of agents towards these three options can be calculated based on the *AttValue* and the *AttWeight* every agent gives to the attributes of lamps such as price, light quality, and efficiency. Since this paper aims to study the effect of group behavior on the behavior of agents, we assume that attitude of agents towards the three options will not change during the simulation and for every agent we assign three random numbers (uniform number between 0 and 1) as attitudes toward the three options. We assume that in the sake of social pressure agents will choose the option with highest attitude. Then they will shape their intention which is composed of their attitude and social pressure from the different groups towards the options.

In this example agents are influenced by the states of two direct-groups (family, and colleagues) and by two indirect groups (e.g, movie star) with different effectiveness. In order to evaluate the behavior of agents, we run the model with different effectiveness of groups (0.4, 0.6) which is similar for direct and indirect groups and different weights that agents give to their attitudes (AW) and social pressures ($DSPW$, $IDSPW$). We assume SPW as the summation of $DSPW$ and $IDSPW$ as the weight that an agent gives to the social pressures from both direct and indirect groups.

Model Results At the beginning of the simulation the number of people that have chosen every kind of lamp is almost equal. Figure 3 presents the effect of different AW and $DSPW$ and $IDSPW$ on the behavior of agents. As it is depicted, when AW is higher than SPW ($DSPW + IDSPW$) although some agents at the beginning of the simulation modify their opinion due to social pressure but a number of them will stop to converge to a specific opinion and will keep their opinion. The increase in AW , results in more agents keeping their original opinion which is based on their own attitude.

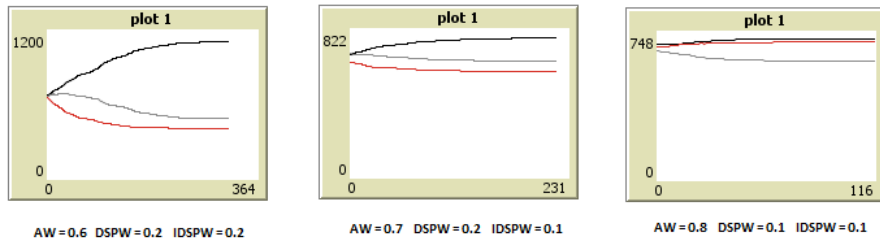


Fig. 3. The number of people choosing different kind of lamps with AW higher than SPW

As it is depicted in Figure 4, increasing the SPW will result in the convergence of agents behavior to a certain opinion. The increase of the weights of social pressure will result in agents converging faster to a specific opinion.

In the case of equal AW and SPW , agents will converge to a specific opinion during a longer time of simulation in comparison with the cases that SPW is higher than AW .

5 Discussion and Conclusion

In order to explore the role of aggregated states of systems on the behaviors of agents, we proposed a method which presents how the decision making process of agents is influenced by the overall behavior of groups.

In agent-based modelling, it is common that agents do not take into account the aggregated behaviors of system and mainly focus on interactions or environmental states. However, in reality agents are influenced by the overall behavior

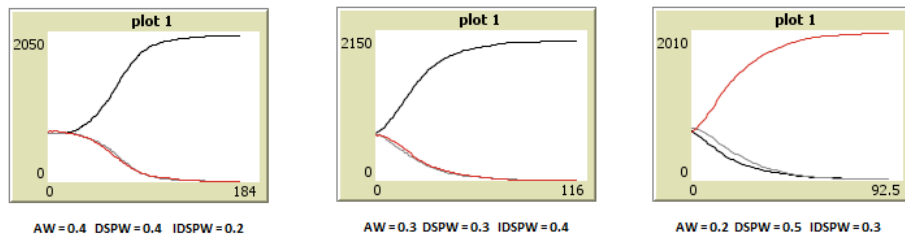


Fig. 4. The number of people choosing different kind of lamps with SPW higher than AW

of not only the system as a whole but also groups of agents whether they belong to them or no. In fact, the system can be considered as the biggest group that the agent belongs to. These groups may overlap. Furthermore, the overall behaviour of these groups may even be in conflict and thus the agent would need to prioritize the group that is most influential to her.

In order to implement the role of group behaviors on the behavior of agents, we proposed a conceptual framework that is mainly inspired from Theory of reasoned Action (TRA). We also used the literature on opinion dynamics to explain how agents choose from various options based on their own attitudes as well as the social pressure coming from groups.

To build this framework, we made several assumptions based on the psychological literature we studied. First, we assumed that the number of people in every group that has chosen a specific option will determine the amount of social pressure towards that option. Second, we also assumed that agents have perfect information about the behavior of other agents. However, we are aware that in reality, individuals may underestimate or overestimate the prevalence of a behavior in a society.

As this paper aimed to study the effect of groups behavior on the behavior of agents, we did not focus on the role of interaction between agents. Interactions result in changes in the value and the weight of different options which consequently influences agents' decision. Besides looking more into interactions, in our future work, we will also look at how agents would only look at groups and individuals with close attitude and intention, referred to as bounded confidence [8].

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