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Reducing diffusion time in attitude diffusion models through agenda setting.

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Abstract

Attitude diffusion is where "attitudes" (general, relatively enduring evaluative responses to a topic) spread through a population. Attitudes play an incredibly important role in human decision making (for instance, in health care decisions) and are a critical part of social psychology. However, existing models of diffusion do not account for key differentiating aspects of attitudes. Using childhood vaccination as a motivating example, we develop the "Multi-Agent, Multi-Attitude" (MAMA) model which incorporates several key factors of attitude diffusion: (1) multiple, interacting attitudes; (2) social influence between individuals; and (3) media influence. All three components have strong support from the social science community. Using the MAMA model, we re-visit the problem of influence maximization in a attitude diffusion setting where media influence is possible – we show that strategic manipulation of the media can lead to statistically significant decreases in diffusion of attitudes. Finally, we use an absorbing Markov chain to explore this phenomenon.

The Importance of Attitudes

Attitudes are "general and relatively enduring evaluative responses to objects" where objects can be "a person, a group, an issue or a concept" [VC03, Page 1]. Attitudes play an important role in many human decisions, including:

1. Product purchasing (for instance energy efficient products, [GKL13])
2. Health related behaviors (for instance, childhood vaccines, [PWVR$^+$13])

Attitudes are subject to "social influence" from friends, family and peers [EPL09].

Given that attitudes inform important behavior and that attitude can change due to social influence, we feel it is critically important to study attitude diffusion using multi-agent social simulation

Understanding attitude diffusion – the spread of attitudes – will allow us to anticipate *behavior diffusion*.

Theoretical Background

Cognitive Consistency

1. Attitudes are not independent – they can influence each other.
2. Cognitive consistency (CC): Hypothesized drive for individuals to have attitudes that are "consistent" with each other.
3. Inconsistent attitudes (like a positive attitude towards recycling and littering) can cause *cognitive dissonance*.
4. CC is an important factor in attitude change [RCMY08, SSR04].
5. Two important factors about attitudes:
   (a) Attitudes that are inconsistent with other related attitudes are more likely to change.
   (b) Attitudes that are related to many other attitudes are less likely to change.

Media Effects

1. Media can influence attitudes.
2. Simplest effect: *agenda setting* – setting the topic to discuss [VG10, McC05].

MAMA Model

The MAMA model has two levels, the social level which captures the interaction between agents, and the cognitive level that captures the interactions of attitudes within an agent.

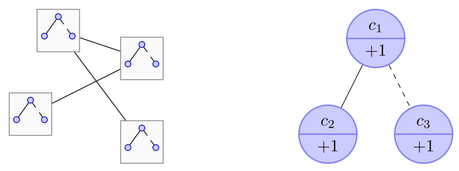

Fig. 1: Social network (left), cognitive network (right)

Networks $G_s =< V_s, E_s >$ is the social network. $G_c =< V_c, E_c >$ is the cognitive network.
Cognitions Cognitions represent any entity towards which an individual can have an attitude, such as people, places and things; but also to more abstruse entities like values. They are the vertices of the cognitive network.
Cognition interaction $w(k, q)$ is the weight of $(c_k, c_q) \in E_c$. $w(k, q) \in \{1, -1\}$
Cognition Value Attitude towards a cognition is called the "value" of the cognition: $v(i, k)$ is value of cognition k of agent i.
States There are $m = 2^{n_c}$ value assignments for a cognitive network, which we call a *state*, labelled: $s_1 \dots s_m$. $s_p(k)$ is the value of cognition k in state p.
Agenda A probability distribution over cognitions: $\pi = [P(c_1), \dots, P(c_{n_c})]$. Determines which cognition is chosen to change per timestep (See Figure 2. Agenda types:

1. *Time-Independent Agenda* (TIA): Fixed probability distribution over the cognitions.
2. *Time Varying Agenda* (TVA): Agenda that changes over time. Fo example, From timestep 0 to timestep 1000, the agenda may be $\pi_{1000} = [1/3, 1/3, 1/3]$, but from 1000 onwards, the agenda may be: $\pi_\infty = [1/9, 1/9, 7/9]$.

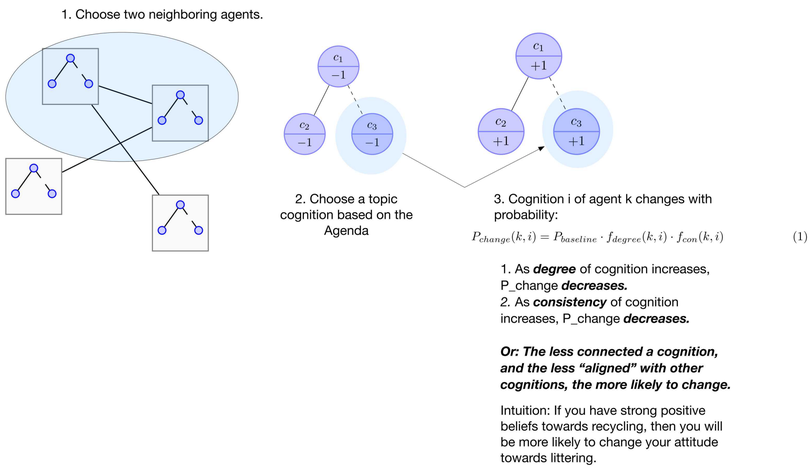

Fig. 2: Dynamics of the MAMA model

Experiment: Time Varying Agendas

In this experiment we study time varying agendas. We consider pairs of agendas.
Experiment setup:

Measure Mean diffusion time: Number of timesteps till 90% convergence to a pre-specified *goal state*.
Cognitive Network All agents have a "3-Fan" network as shown in Figure 1.
Goal state $s^* =< +1, +1, -1 >$
Initial conditions 10% in goal state, rest assigned $s' =< -1, -1, +1 >$.

Definitions:

Boundary Let b be the timestep at which the agenda changes.
Agenda 1 Let π_b^k be an agenda that was used from timestep 0 to timestep b, which sets cognition k to $p \in [0.3, 0.9]$ and the other two cognitions to $(1 - p)/2$.
Agenda 2 Let $\pi = [1/3, 1/3, 1/3]$ be the agenda after timestep b.

Parameters to vary: p, k and b.

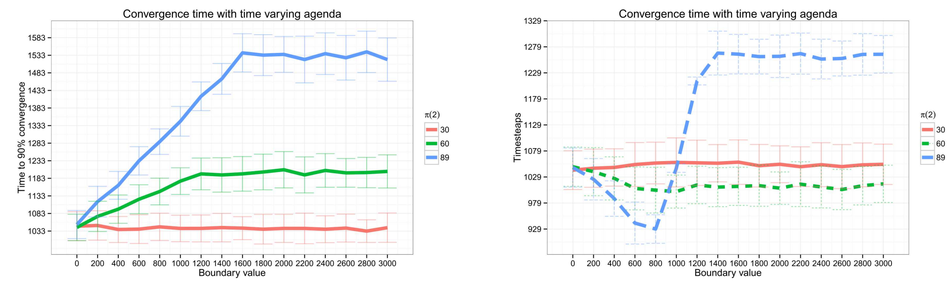

Fig. 3: Mean diffusion time over 100 runs. Each line represents a different p. Left, $k = 1$. Right $k = 2$

Markov Chain Analysis

Questions;

Question 1 Why does focusing on the cognitions 2 & 3 reduce diffusion time (in contrast to a uniform agenda)?
Question 2 Why does focusing on cognition 1 cause an increase in diffusion time?
Question 3 Why is there an increase in the time to convergence after a certain boundary value (b^*) (Figure 3)in the time varying agenda?

To study these questions we use a Markov Chain to analyze the dynamics.

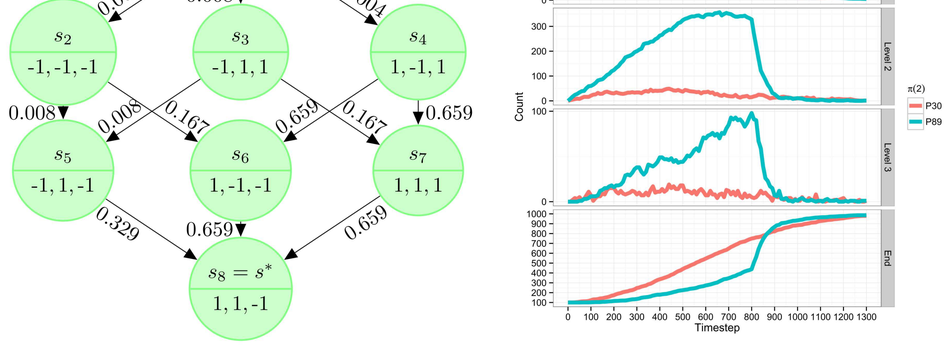

Fig. 4: **Left:** Markov chain of state transitions, with edges labeled by $P_{change}(i)$ Not accounted for: the agenda π and the distribution of agents over states. The bottom of each node are the values for the state. **Right:** Results from a single run. Distribution of agents across states. Level 2 = $s_2 + s_3 + s_4$, Level 3= $s_5 + s_6 + s_7$

Question 1 TVA agenda push more agents out of start state.
Question 2 Reach saturation point.
Question 3 Undue focus on a single cognition.

Conclusions

1. Adding attitudes increases the diffusion time, as compared to a standard voter model.
2. Agenda-setting can significantly affect diffusion time – both positively and negatively.
3. The best agenda for the "3-Fan" network is a time varying agenda that focuses on an ancillary attitudes first, then goes back to a uniform agenda. This agenda can reduce mean diffusion time by ≈ 100 timesteps, which for the 1000 node network we studies, would be a reduction by $100,000$ agent interactions.

Impact:

1. Develop a new model of attitude diffusion.
2. Existing models do not account for complexity of attitudes.
3. Results suggest a multi-stage ad campaign better than focusing on a single topic.

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