Putting a number on opinion dynamics in a population

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Opinion formation in a large population is influenced by both endogenous factors, such as interaction with one's peers—in-person and via social media—as well as exogenous factors, such as the media, of which mainstream media is one of the most influential factors. For example, according to a study conducted by the National Bureau of Economic Research in 2006, after the introduction and expansion of Fox News in the United States between 1996 and 2000, an estimated 3-28% of the audience was persuaded to vote Republican.

In a recent paper published in the *SIAM Journal of Applied Dynamical Systems*, authors Anahita Mirtabatabaei, Peng Jia, and Francesco Bullo use a mathematical model to study the process of information assimilation in a population resulting from such exogenous inputs.

"In any modern society, individuals interact to form opinions on various topics, including economic, political, and social aspects," says author Francesco Bullo. "Opinions evolve as a result of the continuous exchange of information among distributed individuals and of the assimilation of information distributed by media."

Developing quantifiable descriptions of societal opinion dynamics allows us to determine the effects of such information distribution. "It is a central question whether the interaction and assimilation process in a population leads to a socially beneficial aggregation of information," Bullo adds. "Models of opinion dynamics in social networks are strongly inspired by distributed dynamical systems observed in statistical

mechanics, economics, and biotechnologies."

So how is math used to quantify opinions? "In our investigation, we quantify opinions by real numbers that describe the attitude of an individual in relation to an issue, which is updated by averaging peers' opinions," explains author Anahita Mirtabatabaei. "This method provides a good approximation of the behavior of a large population without relying on detailed social psychological findings."

The model takes into account "bounded confidence," which is the observation that individuals interact only with those whose opinions are close to their own. "An individual only receives information from individuals and media in his or her confidence bound, i.e., with those opinions close enough to his or her own," Mirtabatabaei says. "This idea reflects filter bubbles, a phenomenon in which websites use algorithms to show users only information that agrees with their past viewpoints, as well as selective exposure, a psychological concept broadly defined as individuals' tendency to rely on familiar viewpoints."

The model factors in "partisan resistance," the observation that a voter or decision maker ignores the message from an opposing political predisposition. The authors also take into account the increasing popularity of social media technologies such as blogging and tweeting, which publicly rebroadcast messages with added bias. The variance or discrepancy can represent how much bias is inserted in the rebroadcast, among other things.

"In recent times, the direct influence of the media on the public has been augmented by indirect effects of blogging and social networks," says Mirtabatabaei. "Accordingly we model media influence as a background Gaussian signal input centered on the opinion of an expert." Gaussian functions are widely used in statistics to describe normal distributions; they are used to determine the probability that any observation will fall

between two given limits or real numbers. "The variance of this Gaussian input depends on many factors such as message repetition, the expert's importance, public's different interpretation, and blog's rebroadcasting," Mirtabatabaei explains.

The authors also determine the portion of the population that will be attracted to the input's center opinion, referred to as the 'attracted population.'

"We establish that the attracted population is an increasing function of a population's confidence bound [how close it is to their opinion] and media input's standard deviation [how much biased rebroadcast of the message occurs] and a decreasing function of the input's measure (how strongly the message is being broadcast by the media). This result suggests that a higher biased rebroadcast of the media's message by various blogs, and/or larger public's confidence bound results in the attraction of a larger population to the advertised message," says Mirtabatabaei.

Further, the study was validated by verifying that it follows known properties of opinion evolution. "We provided a validation of our opinion dynamics model by verifying that their evolutions have basic known properties, such as clustering of opinions [opinion dynamics models have established that people tend to aggregate into groups of equal-minded individuals], social learning that occurs in a social context when sufficient information is available, and manipulation effects caused by misleading input," says Jia.

While the research in the paper corroborates some generally intuitive facts about information assimilation in a society, the authors establish various mathematical properties of the system's dynamics with constant inputs, which can be used to fully understand the input's influence on overall population and on the eventual emergence of opinion clusters.

Strategic opinion manipulation through planned information dissemination could be one desired effect. Future directions would involve studying time-dependent inputs and their effects on opinion manipulation vs. constant inputs.

Another direction for future work is the study of multiple inputs of information. "One main future challenge is the study of information assimilation and evolution of public opinions when multiple inputs are considered, for example, when two competing parties debate over their different viewpoints in the mainstream media," says Jia.

More information: Eulerian Opinion Dynamics with Bounded Confidence and Exogenous Inputs, Anahita Mirtabatabaei, Peng Jia, and Francesco Bullo, *SIAM Journal on Applied Dynamical Systems*, 13(1), 425 (Online publish date: 11 March 2014). The paper is available for free download at the link above until August 22, 2014. epubs.siam.org/doi/abs/10.1137/130934040

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