Collective Political Opinion Formation in Nonlinear Social Interaction

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Abstract

We have presented a numerical model of a collective opinion formation procedure to explain political phenomena such as two-party and multi-party systems in politics, political unrest, military coup d’etats and netizen revolutions. Nonlinear interaction with binary and independent decision making processes can yield various collective behaviors or collective political opinions. Statistical physics and nonlinear dynamics may provide useful tools to study various socio-political dynamics.

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1. INTRODUCTION

In social sciences, such as sociology, demography, regional sciences and economics, non-linear social interaction between human individuals has been analyzed in detail [1–8]. Some examples include collective behaviors, collective political opinion formation, emergence of social dilemmas, regional migration of interactive populations, settlement formation on the various spatial scales, and market instability in non-equilibrium economics. Collective decision making procedures and policy determination produce unstable and unpredictable outcomes, referred to as nonlinear and chaotic behavior, in a socio-dynamic system. Evidence of this is readily found in the field of financial markets. As the simplest model to explain collective opinion formation, it is quite natural that a large class of these individual decisions may be binary, which is similar to McCulloch-Pitts’ neuron [9], from a sociological perspective on individual behavior. These binary strategies or choices are basic ingredients to determine an individual’s character, the stability or health of a society, and even a financial market’s efficiency.

Opinion formation of individuals within their own political systems is a typical example that can be examined and investigated. A political party is a political organization that subscribes to a certain ideology and seeks to attain political power within a government. The party’s policies often represent an aggregation of interests within the party. These interests will inevitably vary considerably, even amongst party members. The simple case of two political opinions corresponds to two-party systems, for example, the Democratic and the Republican parties in the USA, where these two political parties are dominant. In contrast, the Italian political system is a multi-party system. In a multi-party system, there may exist two strong parties, with a third party that is electorally successful, as found in the UK and Canada. The party may frequently come in second place in elections and pose a threat to the other two parties, but has still never held government formally. Finland may have an active three-party system, in which all three parties hold top office. It is very rare
for a country to have more than three parties who are all equally successful, and all have an equal chance of independently forming government. In cases where there are numerous parties, no one party often has a chance of gaining power, and parties must work with each other to form coalition governments. Sometimes existence of multi-parties lead to a political spectrum where the left is associated with radical or progressive policies and the right with conservative policies.

Statistical physics and synergetics provide us with a powerful tool to examine and study social phenomena with nonlinear interaction, both qualitatively and quantitatively. The physical scheme wherein the behavior of an atom is influenced by the presence of other atoms is similar to the assumption within social science that one person’s decisions depend on the decisions of the others. The process of going from one atom to many atoms in bulk has much in common with the process of one individual proceeding to a social group or organization. Physics has been successful in describing macroscopic behavior using microscopic variables, and thus the somewhat ambitious application of statistical physics to complex social phenomena based on well-established physical formalism is not illogical.

2. Models

Let us consider a model of binary decisions made by a separate group of individuals who maintain a common interest. The collective behavior of people deciding to vote for or against a political party can be modeled. Each individual can make a choice w. w can be coded as 0(against) or 1(for), which can be viewed as two elements in Iching [10], i.e., yin and yang. Yin and yang are a philosophical concept, a means to generalize two opposite principles that may be observed in nature. The terms yin and yang are applied to express dual and opposite qualities, for example, day and night, brightness and dimness, movement and stillness, heat and cold, upward and downward directions, etc.

The theory of yin-yang holds that everything in nature has two opposite aspects that
are mainly reflected in their ability to struggle with, and thus control each other. Warmth and heat can repel coldness, while coldness may lower a high temperature. The yin or yang within any phenomena will restrict each other through competition and opposition, which can be a binary decision made by our God in nature. In China, Japan, and Korea, it is widely believed that the relative physiological balance in the human body will be destroyed and disease will arise if for any reason this mutual opposition results in an excess or deficiency of yin or yang.

In order to describe this dichotomy between for and against, we employed a fashion model with social interaction [11] in this study and modified the utility function as

\[ V = \beta x^\alpha (1 - x)^\gamma - b, \]  

(1)

where \( \alpha \) or \( \gamma \) are control parameters to represent the support index of "for" or 'against' opinions. \( \beta \) is a coupling constant that is related to a social temperature \( T \), \( b \) is a threshold that determines the health state of a social system, and \( x \) is the rate of binary choice, for example pros or cons \((0 < x < 1)\). The dynamical system of binary choice can then be expressed as

\[ x_{i+1} = \frac{1}{1 + \exp\left[ -\beta x_i^\alpha (1 - x_i)^\gamma + b \right]} \]  

(2)

In this equation, it is assumed that the process of creation or transformation of political opinion can be modeled as a flow of social interactions between people with different opinions. Due to the distribution of political opinion at any moment and of the permeability of the people to social interaction, the individuals favor and support a specific opinion. This model may be applied to collective political opinion formation and it is examined through numerical experiments.

3. Numerical results

The model behaviors, which are used to deduce the decision-making procedure of collective opinion in a society, are classified into three categories, stable convergence, stable
periodic oscillation, and unstable periodic oscillations leading to chaos. They can be interpreted in terms of a unification of single dominant group opinion, two or three definite but rival opinions in conjunction with period, and a chaotic or uncontrollable state mixed with numerous rival opinions.

Fig. 1 shows a bifurcation map for stable convergence or bi-stability, such as two definite 'for' or 'against' opinions with $\alpha = 0.2$, $\gamma = 0.8$, $b = 3$ and a varying constant $\beta$. For $\beta < 6.42$, i.e., a high temperature region, the curve converges to a fixed point. This means that a single and unified opinion of individuals may emerge within their own political systems. When $6.42 < \beta$, i.e., a low social temperature region, there are two split curves, and the iterates of all $x$ are attracted to the 2-period cycle. This corresponds to a stability of two independent and concrete political opinions under social temperature low enough to excite two modes. There are two parties, such as the majority and the minority party in a democratic political system, for example long-lasting Democratic or Republican parties in the American political system. No other collective opinions except two independent ones or emergent behavior of two modes can be possible in this society, which may be regarded as politically stable and healthy due to various public opinions influenced by the mass media, the Internet, and government or non-government organizations.

Fig. 2 also shows a bifurcation map for stable convergence, bi-stability, tri-stability, and chaotic behavior with $\alpha = 0.5$, $\gamma = 0.5$, $b = 3$ and varying social temperature $\beta$. For $\beta < 9.35$, i.e., a very high social temperature region, the curve converges to a fixed point again. When $\beta = 9.35$, two curves start to appear again, and the iterates of all $x$ are attracted to the 2-period cycle, such as majority and minority opinions. The two curves are subsequently divided into 4 curves and the iterates of all $x$ are attracted to the 4-period cycle. A single majority opinion is split into two majority opinions, which can eventually be unified back into a single majority opinion in some cases. The single minority opinion is also split into two opinions. A window with a 3-period cycle is also detected at approximately $=18.5$ on the upper tongue of the bifurcation diagram (inset in Fig. 2).
There exists a single intermediate opinion, a so-called third party’s opinion, in addition to both the majority and minority opinions. The collective opinion curve can also be detected as periodic or chaotic as an intermittency route in various social temperatures, leading to political unrest. The chaotic behavior of collective opinions represents political chaos and unrest due to revolutionary breakdown, war, financial crisis, or terror. The former apparent eternity and sudden collapse of eastern communist leaderships can be explained through this political unrest.

One stable opinion, two rival opinions, four different opinions, three opinions, and chaotic states of many different opinions occur with varying social temperature. Occurrence of chaotic states is eventually accompanied by social development, harmony and action to equally double political opinions. There is no cosmos without chaos.

The periodic or chaotic opinions depend on underlying political dynamics controlled by various control parameters, $\alpha$, $\gamma$, and social temperature $\beta$. The parameters may be somehow related to the society’s political health, such as the government’s characteristics, the relationship between the media and non-government organizations, or the Internet and the government, people’s understanding of or activity toward democracy, and society’s collective behavior.

4. Conclusions

It is demonstrated that collective opinion formation emerges in nonlinear interaction in terms of unstable, periodic or even chaotic patterns of behavior. The aim of this paper is to formulate a numerical model of opinion formation or a collective decision-making procedure using binary and independent strategies. This binary strategy can be thought of as the two elements yin and yang in Chinese philosophy, and produces various phenomena in nature on many specific conditions. Nonlinear interaction can be numerically realized in terms of social structure, information asymmetries or an information cascade in a real life social network,
complex electoral processes, decision making processes, etc. A combination of nonlinear interaction and binary strategy may be the mother of various political actions or societal behavior.

References

[1] W. Weidlich, G. Haag, *Concepts and Models of Quantitative Sociology* (Springer Berlin, 1983).

[2] W. Weidlich: *Physics and science: the approach of synergetics*, Phys. Rep. **204**, 1 (1991).

[3] S. Galam, J. Stat. Phys. **61**, 943-951 (2004).

[4] S. Galam, Physica **A 274**, 132-139 (1999).

[5] S. Galam, Physica **A 320**, 571-580 (2003).

[6] D. Helbing, *Quantitative Sociodynamics* (Kluwer Academic Dordrecht, 1995).

[7] N. Durlauf, Proc. Natl. Acad. Sci. USA **96**, 10582-10584 (1999).

[8] F. Schweitzer, J.A. Hoylst, Eur. Phys. J. **B15**, 723-732 (2000).

[9] W.S. McCulloch, W. Pitts, Bull. Math. Biophys. **5**, 115-133 (1948).

[10] R. Wilhelm and C. F. Baynes, *The Iching or Book of Changes* (Princeton University Press, 1977).

[11] S. Nakayama and Y. Nakamura: Physica A **337**, 625-634 (2004).
FIGURE CAPTIONS

Fig. 1. Bifurcation map for social temperature $\beta$; $\alpha = 0.2$, $\gamma = 0.8$, and $b = 3$.

Fig. 2. Plot of $x_{i+1}$ versus $x_i$ in the case of $\alpha = 0.5$, $\gamma = 0.5$, and $b = 3$. 
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