Social Equation of State

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Abstract

A social system is often viewed a set of people as human molecules contained in a system. The social human behavior which is called as "state" of social system is modeled from a physico-chemical approach. The social equation of state (SEOS) strongly related to the degree of dissatisfaction or satisfaction with the political, economic, cultural and social rules. In this work, based on the concept of universality in statistical physics, a new SEOS is presented for a hypothetical non-interacting people social system. The social "pressure", "freedom" and "excitement" are respectively defined as a measure of different social rules, individual rights and people motivation. Then the proposed SEOS is extended to real social system containing interacting people. The human interactions are divided into two parts: the strong family interactions and usual social interactions. Their contributions to the proposed SEOS have been considered based on a statistical thermodynamic approach. The proposed SEOS is used to derive an expression for social entropy changes.

Keywords: Social equation of state, Statistical physics, Human behavior, Social system, Human interactions, Social entropy change

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1. Introduction

Modeling of social behavior in a society involving interacting people is a challenging problem because the knowledge of human interactions is a key factor to success in different activities, e.g. business, friendship, marriage and life and especially for the natural crisis managements (Mohsen-Nia et al., 2011; Libb, 2008; Carrington et al., 2005). Considering the important role of the social behavior knowledge on the social managing science, many attempts have been made to apply the accurate models for describing the human behaviors (Palla et al., 2007). Due to the complexity of human interactions, in many cases, human behavior is typically modeled only at the level of a single person (Huynh et al., 2008). Although, the individual human behavior has an important role on the social behavior especially when his or her decision is a crucial and major determinant of the society's management programs, in the most cases, the individual decisions are also affected by human interactions. Therefore, the mutual relationship between local individual behavior and global social structure makes the human behavior representation as a complex topic (Pan et al., 2005). In economics there are various different approaches to making physics-based mathematical models tractable by gross simplification of human behavior that might make sociologists blanch. But sociology, while trying to find a scientific method, has been loath to abandon a more complex psychological-based methodology of human behavior (Ball, 2002). However, based on the concept of universality in statistical physics, the 'universal' features analogous can be considered as a basic assumption in the study of complex human systems. So, it is remarkable that the modern statistical physics theories may be used for study of the collective behavior of components e.g., human molecules or fluid molecules.

Due to their individual character and repulsive and attractive interactions of components in systems at the specific conditions, phase transitions may be expected. It does not really matter what system is observed and only the influence of interactions between components in the system is the key factor for the phase transition prediction that is explored in physics-based models of social behavior (Ball, 2003). An analogy in statistical physics might be the way in which the state, behavior and phase transitions of a system of interacting components can be evaluated. In this method, the properties which define the 'universality class' of the system depend not only on the individual characteristics but also on the collective behavior. The most important factors are the dimensionality of the system and the long-or short range forces (Schelling, 1978).

The social structure may be considered as a mixture (collection) of interacting components (persons) with different characteristic factors (Carey, 1858-59; Hirn, 1868). However, for simplicity, the collection can often be treated as a pseudo pure component. In this manner, a "social equation of state" (SEOS) can be used for evaluating the social human behavior at least for societies with low diversity in different conditions. Therefore, this approach shows a quantitative way to study the role played by individual human personality and human interactions in shaping the kind of aggregate behavior observed at a population level in social structures. This model can be used for determining social entropy which is a key factor in social managing operations.

2. Social equation of state

In physics and thermodynamics, an equation of state is a relation describing the interconnection between various macroscopically measurable properties of a system under a given set of physical conditions. It is a constitutive equation which relates the thermodynamic variables of pressure (p), temperature (T), volume (V) and number of molecules (n). For a given amount of non interacting particles contained in a system, the thermodynamic variables are not independent quantities; they are connected by the following well-known ideal relation (Mohsen-Nia, et al., 2011):

$$p = RT\rho \qquad (1)$$

where, $\rho = n/V$ is number density. Based on the thermodynamic concept, let us redefine some social variables for the social systems:

Closed System: a closed system is chosen and must clearly be defined for the purpose of the study of a particular society.

Internal energy, U: is the amount of energy which is stored in a society and accounts for the movements of people which constitutes the society.

Heat, Q: Heat is that form of energy that is sustained by the difference of society excitement between the two systems as a driving force.

Pressure, *p*: is social pressure that is really a measure of existence of different rules, e.g. political, economic, cultural and social rules which should be obeyed by all people in such a system to avoid totally chaotic systems. Of course, sometimes the pressure may be applied for the restriction of freedom by current government systems.

Social freedom, V: is the social freedom

Social excitement, *T*: is social excitement as a measure of the society's motivation

Number density, $\rho = n / S$: is social system population per unit area

Work, W: Work is an interaction between the system and its surroundings. This is a form of energy that flow between a system and its surroundings. In the thermodynamic systems, more commonly this may be expressed as pressure times a change in volume in the system interacting with its surroundings. In the social systems, the work can be defined as $p\Delta V$ which is a measure of necessary energy for making a regular social system.

Entropy, S: It is social system disorder. From thermodynamic view point, it can be defined as $\Delta S = \Delta Q / T$ or $dS = dQ / T$ for reversible processes. The same definition may be used for variation of social entropy.

A human society system may be defined as a nation or any social-political unit for this analysis. In mathematical form, for a hypothetical non-interacting system, the SEOS can be stated as:

$$pV = \text{constant} \qquad (2)$$

> "From the thermodynamic approach, for fluids, the above relationship has also been attributed to Edme Mariotte and is sometimes referred to as Mariotte's law. However, Mariotte's work was not published until 1676" (Sarkar, 2006).

Where, V is referred to social freedom. Following the ideal fluid equation of state, eq. 1, the ideal SEOS can be presented in the following form:

$$pV = \Re T \tag{3}$$

where, T is the social excitement and $\Re$ is a constant. According to eq. 3, in a social system, the social pressure, p is related to the social freedom, V and the social excitement, T. This hypothetical model can be used for an ideal non-interacting social system. Since the social behavior is really depended on the past transformations of the society system, the constant $\Re$ in eq. (3) cannot be considered as a general constant for various society systems. Actually considering the effects of the culture, religion and history on the education process, behavioral pattern and psychology-based personality of people in a specific society system, the constant $\Re$ can be obtained separately for each system. For a real system, the model should be modified by considering human interactions as a key factor for the realistic evaluation of human societies. Based on the thermodynamic approach, a symbolic expansion model is proposed in the following form:

$$p = \frac{\Re T}{V} + B_{(T)} \frac{\Re T}{V^2} \tag{4}$$

where $B_{(T)}$ is a social excitement (T) dependent coefficient. The coefficient $B_{(T)}$ has several contributions depending on dominant interpersonal interactions between people. For a real human society, two kind of human interactions are dominant. The family interactions which lead to family formation are represented by $B^f_{(T)}$ and social interactions are represented by $B^s_{(T)}$. Therefore, for a real society, B is separable into the two parts in the following form (Mohsen-Nia, Modarress, 2007):

$$B_{(T)} = B^f_{(T)} + B^s_{(T)} \tag{5}$$

By combining Eqs. (4) and (5), the social equation of state can be presented as:

$$p = p^f + p^s - \Re T / V \tag{6}$$

Therefore, the family pressure and social pressure terms must be evaluated. In this manner, for simplicity we assume that $p^f \cong p^s$, so we have:

$$p = 2p^s - \Re T / V \tag{7}$$

According to eq, (4), the social pressure term can be presented in the following form:

$$p^s = \Re T / V + B^s_{(T)} \Re T / V^2 \tag{8}$$

Substituting the above relation into eq. (7), the social equation of state is proposed as:

$$p = \Re T / V + 2B^s_{(T)} \Re T / V^2$$

Based on a statistical thermodynamic approach, the $B^s_{(T)}$ can be determined by using a realistic interaction model in the following form (Schrödinger, 1989; Hill, 1987):

$$B^s_{(T)} = -2\pi \int_0^\infty r^2 (e^{u(r)/T} - 1) dr \tag{9}$$

where r is the interpersonal personality distance which can be evaluated by a standard personality assessment test as is introduced in the previous work and $u(r)$ is the interpersonal potential model. To avoid unwarranted complications, it proves useful to restrict our choice to those models established for no more than two independent parameters as presented in the previous work. Therefore, using the interpersonal potential model the SEOS can be obtained. The proposed SEOS may be used for some important social characters such as social entropy.

3. Entropy changes for a social system

The Second Law of Thermodynamics deduced the principle of the increase of entropy and explains the phenomenon of irreversibility in nature. It expresses the irreversibility of actual physical processes by the statement that the entropy of an isolated macroscopic system never decreases. In a human society, without society's own ability to create organized systems and sub systems, the second law predicts a chaotic situation for human society. A nation or any major political unit may be defined as a human society for this analysis. While different rules, e.g. political, economic, cultural and social rules are observed and followed by the individuals within the system, the system will be orderly, "regular". Although the majority of people follow the society rules, but in different full stress situations e.g., different natural disaster such as: flood, tornado, hurricane, volcanic eruption, earthquake, heat-wave, or landslide which it leads to financial, environmental or human losses. In these situations normally, minority of people may obey the society rules and this may be caused to increase the losses. Of course, sometimes the disorder is a precise measure of expressed dissatisfaction with the society rules or the current system. Anyway the social entropy can be considered as a realistic measure of people's response to their situation. Therefore, from the social management social science, the measurement of the social entropy and defining a methodology for evaluation of the disorder in society especially in the specific conditions is very important.

The first law of thermodynamics is the conservation of energy principle: The change in internal energy of a system is equal to the heat added to the system plus the work done on the system:

$$\Delta U = Q + W \qquad (10)$$

Differentiating we have:

$$dU = dQ + dW \qquad (11)$$

Since $dS = dQ/T$ and $dW = -pdV$ then:

$$TdS = dU + pdV \qquad (12)$$

Therefore,

$$dS = \frac{1}{T}dU + \frac{p}{T}dV \qquad (13)$$

The social internal energy has a proportional relation with the excitement of society, *T* which may be expressed in the following form:

$$U = CT \qquad (14)$$

Where, C is a constant, so we have:

$$dU = CdT \tag{15}$$

Therefore, for a real system, the entropy change can be obtained in the following form:

$$\Delta S = C\int \frac{dT}{T} + \int \frac{p}{T} dV \tag{16}$$

Based on the social excitement evaluation of the system which can be achieved by a standard questionnaire and statistical analysis, the first term of the above equation can be determined. For the second term, the social equation of state and a simple graphical or numerical method can be used for the entropy calculations of social system.

Entropy changes for a social system in the full stress situations or natural disasters

Considering the important role of accurate prediction of entropy change especially in the different natural disaster in disaster management processes, eq. (16) can be used for evaluating of the entropy change. The entropy change of a social system is the difference between the final and initial states. The initial state is considered as a hypothetical reference state (T_0, p_0, V_0) that the entropy of the system is zero. Therefore, using eq. (16), the entropy change can be derived in the following form:

$$\Delta S = C\ln T + \int \frac{p}{T} dV \tag{17}$$

In the shock situation such as natural disaster, minority of people may be affected by the personal interactions and the ideal social equation of state can be considered for the entropy change calculations. Therefore, we have:

$$\Delta S = C\ln T + \Re \ln V \tag{18}$$

According to eq. (18), the first and second terms refer the effect of social excitement and the social freedom respectively. In the shock situation, the social excitement is very high especially in the first hours or days after disaster events. Therefore, the social freedom should be reduced by different management and controlling policies. This may be achieved by applying different social crisis rules as the social pressure for the control and decreasing of the social entropy.

4. Conclusion

A new approach to social system behavior has been developed. In this work, based on physico-chemical theories, the molecular model has been used for prediction of human society behavior. The new proposed SEOS describe the relation between social “pressure”, “freedom” and “excitement” which are a measure of different social rules, individual rights and people motivation respectively. The ideal SEOS which is proposed for non-interacting social system is extended to real social system containing interacting people. The human interactions including the strong family interactions and usual social interactions are considered for the real social system modeling. Therefore, the proposed SEOS can be used for prediction of human behavior in the small and large social systems. The proposed SEOS is used to evaluate the social entropy changes. According to the results, the social entropy change is related to the social excitement and degree of freedom.

References:

Ball P. (2002). The physical modelling of society: a historical perspective, *Physica A* 314, 1-14.

Ball P. (2003). The Physical Modelling of Human Social Systems, *Complexus*, 1:190–206

Carrington P. J., Scott, J. and Wasserman S. (2005). Models and Methods in Social Network Analysis. *Cambridge UP*.

Hill T. L. (1987). *An Introduction to Statistical Thermodynamics*, Dover Books on Physics.

Hirn G. (1868). *Philosophical Implications of Thermodynamics* (Métaphysique et conséquences philosophiques de la thermodynamique: l'analyse fondamentale de l'univers) (Metaphysics and Philosophical Implications of Thermodynamics: Basic Analysis of the Universe). Paris: Gauthier-Villars.

Huynh T., Fritz M. and Schiele B. (2008). Discovery of activity patterns using topic models. *In Proc. of UbiComp*.

Mohsen-Nia M., Modarress H. (2007). Association equation of state (AEOS) based on aggregate formation for pure substance, *Chemical Physics, Volume 336*, 1, 22-26.

Mohsen-Nia M., Arfaei F., Amiri H., Mohsen Nia A. (2011). A Thermodynamic Methodology for Evaluating Friendship Relations Stability, *Journal of Human Thermodynamics*, 7: 5-14

Palla G., Barab´asi A. L. and Vicsek T. (2007). Quantifying social group evolution. *Nature* 446 664-667.

Pan X., Han C. S., Dauber K. and Law K. H. (2005). Human and social behavior in computational modeling and analysis of egress. *Automation in Construction* 15(4), 448-461.

Sarkar S., Pfeifer J., Garson J. (2006). *The Philosophy of Science*: An Encyclopedia, Volume 1, Taylor and Francis group*,* New York, NY 10016.

Schelling T. C. (1978). *Micromotives and Macrobehavior*, New York, WW Norton.

Carey H. C. (1858-59). *The Principles of Social Science* (Vol I, Vol II, Vol III). J. B. Lippincott & Co.

Schrödinger E. (1989). *Statistical Thermodynamics*, Dover Books on Physics.

Thims, Libb. (2008). *The Human Molecule*. Morrisville, NC: LuLui.