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Research Article

PHYSICAL ANALYSIS OF SOCIAL DYNAMICS: A SOCIOPHYSICS PERSPECTIVE

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ABSTRACT: Sociophysics is an interdisciplinary field that uses methods from the physical sciences to study human behavior and interactions. It includes mathematical and computational techniques such as big data analysis, statistical modeling, network theory, and simulations. It analyzes complex systems to understand the dynamics of society. Historically, sociophysics emerged from applying statistical mechanics and thermodynamics to social phenomena. Foundational work has modeled opinion dynamics, crowd behavior, and information diffusion in social networks, and provided insights into consensus, polarization, and social stability. The basic concepts are based on treating individuals as agents, using network theory, and applying statistical mechanics and dynamical systems. Methods include big data analysis, statistical modeling, simulations, and network analysis. Future research will aim to integrate artificial intelligence and machine learning, foster interdisciplinary collaboration, utilize real-time data, and apply findings to public policy. Sociophysics aims to improve our understanding of social systems and solve today's society's complex problems. In this study, the field of sociophysics, its historical development, studies in the literature, and methods were generally discussed.

Keywords: Complex Systems, Dynamics, Sociology, Sociophysics.

1. INTRODUCTION

Human beings have strived to understand past events, experiences, and behaviors and express them. This endeavor has led to the emergence of art and science. These fields have taken different approaches to give meaning to human existence. Religion, art, philosophy, and science have guided this quest [1, 2]. The extraordinary achievements of the modern scientific method have eclipsed these other approaches, reshaping our world through technology. However, this success has had unintended side effects, such as massive knowledge fragmentation and the scientific community's isolation. Unfortunately, learning is now divided into many narrow and isolated disciplines. The alienation that used to exist between the arts and sciences can also be said to apply to the division between natural and social sciences. Experts are generally indifferent and ignorant of the general situation, which leads to confusion and irrelevance in their respective fields. This can lead to frustration, which can be remedied through interdisciplinary cooperation and synergy. Improving communication and regular coordination will increase the integration and consolidation of scientific knowledge, which can solve the problems of confusion and apathy. By emphasizing interdisciplinarity, knowledge in all fields could advance through a better balance between analytical specialization and generalization [3-6].

Scientific progress is always the reconciliation of visible contradictions in a broader framework expanding reciprocities. This process is reflected by these efforts at unification recorded in the history of science, which periodically alternates between expansions and consolidations. Therefore, searching for new models and grand theories is never a novelty [7].

The history of the mind has gone through various analytical and synthetic phases up to the present day. Since the Enlightenment, the lure of science has led many great thinkers to unify human knowledge. Since the Enlightenment, the lure of science has led many great thinkers to unify human knowledge. These include Hegel's phenomenalism, Comte's positivism, and those who believed that sociology should follow physiology. [8, 9]. More importantly, Condorcet and Quetelet's Physique Sociale and Bagehot's Physics and Politics provide outstanding essays, beginning with the Neoplatonists and culminating in the neo positivists.
In contrast to the few grand theories of the last century, this century has seen many minor investigations. The dominant tendency of modern science was, therefore, divisive until the emergence of a unifying spirit that is expanding again today. This cyclical movement has the effect of a pendulum oscillating between the paradigmatic edges of knowledge. Hence, following a period of limited professionalization, knowledge in various fields deepened, and we are now re-emerging into broad generalization, combining the separate findings of different disciplines [10-12].

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The scientific revolution is making the natural sciences more subjective by combining quantum and chaos theories, while the social sciences are becoming more objective. As this approach continues, this convergence can counter and correct the divisive tendencies of recent generations, thus reconnecting knowledge at a new and higher level [13].

Sociophysics is a field that has become popular among researchers since the late 1970s. Although physics usually deals with inanimate systems, sociophysics has also become applicable due to the complexity of the social sciences and the interaction of social phenomena. Adolphe Quetelet and Auguste Comte coined the term sociophysics. While Quetelet defined the concept of the average human being in terms of averages of measured variables, Comte defined social physics as the study of the laws of society and saw this field as an important discipline to complement the scientific understanding of the natural sciences. Comte argued that once the human mind understands various aspects of nature, precise scientific methods can be applied to studying social phenomena [14-17].

Sociophysics is a discipline that uses methods and concepts from the physical sciences to understand the behavior and interactions of human societies. Research in this field often involves mathematical and computational techniques such as big data analysis, statistical modeling, network theory, and simulation. Based on the analysis of complex systems, sociophysics attempts to model the dynamics of societies by studying large data sets to understand the collective behavior of people. In this context, physicists develop mathematical models to describe and predict human interactions [18-20].

Sociophysics has attracted the interest of physicists in the study of social and political behavior and has become a popular area of research. Some problems in the social sciences are new and require a different perspective. Sociophysics can contribute to solving these problems in the social sciences by bringing a new perspective to these problems. Sociophysicists use mathematical and computational techniques to model and analyze social behavior. These techniques include big data analysis, statistical modeling, network theory, and simulation. These methods are used to analyze complex systems and model human interactions. By developing mathematical models, physicists describe and predict patterns of human interactions. However, sociophysics is not just a numbers game; the numbers presented by the models do not represent the whole of reality but indicate certain trends and dynamics. Sociophysics aims to find empirical laws based on real data. Sociophysicists, therefore, aim to provide new perspectives for understanding social and political behavior using real-world data [14, 15, 20-22].

Sociophysics is still at an early stage of development and is far from offering a complete explanation. However, it is important because it offers a new perspective for understanding social and political behavior and explores empirical findings based on real data. Therefore, sociophysics has the potential to bridge the social sciences and physics to provide a more comprehensive understanding of human behavior [18, 23].

Sociophysics can contribute to a better understanding human behavior and interactions using an interdisciplinary approach and mathematical-computational techniques. This understanding can offer potential applications in solving complex societal problems such as consensus building, polarization, and social stability.
In this sense, the research questions of this study can be listed as follows:

- What is the historical development of the field of sociophysics and the place of the main theories in the literature? Which pioneering studies have been decisive in the evolution of the discipline?

- Which research topics have shaped sociophysics from the past to the present, and how are these topics discussed in the literature?

- How have mathematical and computational techniques used in sociophysics been highlighted in the literature, and how have they been applied to understand the dynamics of social systems?

- How does sociophysics research utilize historical and contemporary data sources, and what new scientific discoveries do these data support in the literature?

In this study, the definition of sociophysics, its historical development, the general overview of the studies on sociophysics in the last decade, the basic concepts used in the field of sociophysics, and the methods of analysis have been tried to be discussed.

2. HISTORICAL DEVELOPMENT

Sociophysics is considered a relatively new discipline, but its roots go back to ancient philosophy. One of the first philosophers to try to explain social phenomena was the Greek philosopher Epictetus, who argued that physical laws governed human behavior. In the 18th century, thinkers such as Adam Smith and David Hume developed disciplines they called moral philosophy or political economy, arguing that societies have laws that differ from the laws of physics. Thomas Hobbes, an English philosopher, is considered one of the first to mention the concept of social physics. In 1636, he traveled to Italy, where he met Galileo Galilei, a physicist-astronomer known for his contributions to the study of motion. He started outlining the representation of society's physical phenomena through the laws of motion. Hobbes tried to relate the motion of bodies to the mathematical terms of motion outlined by scientists of the time. However, while the term social physics is not unique, the idea of studying society through scientific methods preceded the very first written reference to social physics [24-27]. To describe the historical development of sociophysics in detail, it is necessary to mention the personal work of the pioneers and their contributions to the field. The theories, methods, and practices put forward by these pioneers formed the cornerstones of sociophysics and played a critical role in the evolution of the discipline. The contributions of pioneering researchers are of great importance for understanding the methodological development of sociophysics and shaping the scientific paradigm in this field.

William Petty was an early pioneer of social physics and authored important works on political economy and statistics. His political arithmetic concept laid one of the foundations of social physics, arguing that society should be analyzed with quantitative data. By encouraging the use of scientific methods, Petty's work laid an important foundation for understanding and predicting the behavior of society [28].

In 1748, Baron de Montesquieu's work 'The Spirit of the Laws' stated that there are laws of society similar to Newton's. In 1784, Immanuel Kant, speaking about universal laws, argued that, however obscure the causes, if we pay attention to the far-reaching free play of the human will, we can see that it is in orderly motion and that what appears complex and chaotic is, viewed as humanity steady and gradual evolution of the original equipment [29, 30].

Pierre-Simon Laplace studied birth statistics in Paris to understand social laws. In 1781, he explained the near equality of these statistics as the expected outcome of a random process. Using the concept of an error curve to describe variations in this and other social data, Laplace showed that this curve applies to everything from human affairs to coins. In 1803, Lettres d'un Habitant de Geneve, Henri de Saint-Simon presented the idea of characterizing society using laws based on laws analogous to physics and biology studies [31, 32].

Upon his arrival at the French Royal Observatory in 1823, Adolphe Quetelet was impressed by the statistical regularities in social data revealed by Laplace and Poisson. Quetelet transformed Comte's "social physics" concept into a mechanistic social science, emphasizing its statistical foundation. In 1832, he posited that the collective human species can be considered within the realm of physical facts. With the increasing number of persons, the individual's will is concealed by a set of general facts that depend on general causes. Quetelet's dissemination of Laplace's data proved to be a significant influence in numerous fields. In 1850, the scientist John Herschel offered a favorable assessment of this work. Florence Nightingale proposed that Quetelet's social mechanics be incorporated into the curriculum at Oxford University. Karl Marx utilized Quetelet's statistical laws to develop his theory of value. Moreover, John Stuart Mill perceived that Quetelet's study supported his conviction that societal and historical processes are subject to immutable laws analogous to natural sciences, though more challenging to comprehend [33-36].

Auguste Comte, one of the founders of sociology, is considered one of the first to define sociophysics in an article in Le Producteur in 1842. Comte called social physics the science of civilization or the study of the laws of society and argued that with social physics, he aimed to complete the scientific explanation of the world begun by Galileo, Newton, and others. Comte argued that since the human mind understood celestial and terrestrial physics, mechanical and chemical physics, and plant and organic physics, only social physics as science remained to complete the set of exact sciences or observations. In sum, Comte defined sociophysics as the science of civilization that studies the laws of society [14, 37, 38].

In 1902, Josiah Willard Gibbs published his "Fundamental Principles of Statistical Mechanics," demonstrating that this new method was well suited for studying non-physical systems in multidisciplinary science. For over 100 years, statistical mechanics and dynamics have been successfully applied to solve social problems [39].

Max Weber argued that social phenomena should be studied objectively and that the laws of social interactions should be investigated [40].

George Kingsley Zipf (1902-1950) discovered how numerical patterns were intriguing in language and social phenomena. He first focused on Chinese writing and found that the frequency of syllables followed a specific pattern. This pattern explained how the frequency of an element varied depending on its order, and it applied to languages like Chinese and English. Extending his research, Zipf applied the power law to city size distributions and discovered that the population of cities follows a certain pattern: the second big city is about half the city size of the biggest city, and the third is one-third the size. This relationship became known as Zipf's Law. Zipf's work was not limited to the study of language and cities. He believed that the power law could be applied to many areas, from word frequency to aspects of human behavior, such as the death wish. He thought these distributions reflected nature and society seeking the most efficient path. Despite criticism, Zipf believed that statistical analysis was a powerful tool for understanding different phenomena. He emphasized the importance of testing with data, stating that he had a vision of the future data age. In conclusion, Zipf's pioneering work contributed to understanding statistical principles in various aspects of human society and prepared the social sciences, especially geography, for the era of data-driven analysis [41-43].

Physicists' interest in the social sciences dates back to a pioneering paper by Majorana in 1936 on the fundamental similarity between statistical laws in physics and the social sciences. Ettore Majorana analyzed the similarities and relationships between statistical physics and the social sciences. Majorana's paper represents an attempt to apply the principles of statistical mechanics in physics to sociology. His ideas are based on the idea that social systems, like natural systems, show certain behavior patterns that can be studied mathematically. This step emphasized the importance of statistical analysis in the social sciences and led the way for the contemporary analysis of complex systems [17, 44, 45].

John Quincy Stewart (1894-1972) was a pioneering researcher in social physics and focused on developing the discipline through his work at Princeton University. His work, closely related to geography, was supported by key institutions and thinkers at Princeton. Stewart sought to prove social physics theory by applying population potential models to geographic distribution. He also tried to demonstrate this theory's applicability by calculating the US population potential and creating equipotential maps [46, 47].

Nicholas Rashevsky (1899-1972), a biophysicist and mathematician, is known for his work on mathematical models of complex systems. He has contributed to the mathematical study of social phenomena [48, 49].

Kurt Lewin (1890-1947) works on force field theory and group dynamics in social psychology. Lewin's work contributes to understanding social phenomena through mathematical and physical principles [50].

Robert K. Merton (1910-2003) does important work in explaining social structure and phenomena using mathematical and statistical models. Merton changed the perspective with a new mathematical modeling of social interactions. However, he contributed significantly to social theory, functionalism, and the sociology of science [51].

Norbert Wiener (1894-1964) initiated the definition of cybernetics and worked on modeling social systems. Wiener thus offered a different perspective by defining new dynamics for social systems [52, 53].

Paul Lazarsfeld, who lived between 1091-1976, perceived the importance of statistical analysis in social research and applied quantitative methods. As a pioneer in this sense, Lazarsfeld's contributions to social sciences have made this discipline more scientific [54].

Anatol Rapoport (1911-2007), a mathematician and social scientist, made significant contributions to analyzing complex systems and modeling social interactions [55, 56].

Thomas Schelling (1921-2016), Nobel Prize winner in Economics, contributed significantly to analyzing complex systems and social interactions. Schelling's research has focused on strategic behavior and decision-making processes in social and economic problems. He has developed innovative game theoretic models to study how decisions are made based on the actions of individuals [57-59].

Serge Garam, born in 1952, focused on analyzing intricate systems and modeling political occurrences. His primary focus was on the dynamics of political trends and the creation of mathematical models to understand social movements and political processes [60-62].

Italian physicist Rosario Nunzio Mantegna was born in 1960. He worked on analyzing economic systems and explored the intricate dynamics of financial markets. He contributed significantly to complex system mathematical and statistical models [63, 64].

As it is currently understood, the field of sociophysics originated in the latter half of the 20th century. In the late 1970s, physicists began investigating the dynamics of social systems and networks. During this period, great advances were made in analyzing and modeling complex systems. In the late 20th century, physicists and computer scientists began to develop new mathematical and computational models to model the behavior of complex systems. These models explained various social phenomena, such as herd behavior, epidemiological spillovers, and market fluctuations. These developments led to sociophysics, a new discipline that studied societies as physical systems. Sociophysics draws on complex systems theory, statistical physics, and computer science to understand how societies work and change. For centuries, statistics has been treated as a social discipline (only in the last century has it been considered, in mathematical terms, as a special universal science about the nature of mass). Still, for the social sciences, statistics is irreplaceable, while for other natural sciences, it is just one of the tools. However, the coexistence of physics and social sciences is a much more complex phenomenon because the objects are no longer physical (people instead of particles, human interactions instead of collisions of molecules, etc.). Physics has been used in social studies only as an analogy and a methodological tool, and in this role, it has competed with the already existing and very well-developed statistics. However, without a doubt, physics can indeed change and enrich the traditional over-statistics view of society. Today, sociophysics is a field where methods such as big data analysis, statistical modeling, and simulation are becoming widespread. The advancement of computer technology has enabled the expansion of sociophysics research and the creation of more complex models. Research in this field has significant potential for understanding the collective properties of human behavior and modeling the dynamics of societies. In the last decade, scientists have made significant progress in understanding the dynamics of nonlinear coupled systems. Thanks to these advances, the macroscopic dynamics of many-body systems, such as social systems or networks, have become popular among statistical physicists. Sociophysics models have been proposed to simulate social behavior and have a similar purpose to the phase separation models studied by physicists [14, 18, 23, 65, 66].

3. LITERATURE REVIEW

While examining the literature, attention was paid to articles in journals, proceedings, and books. Publications with sociophysics in the title between 2014-2024 were considered. Google Scholar was used as the database since Google Scholar includes most databases and searches not only articles but also proceedings and book chapters. ‘Sociophysics’ was used as the keyword in the literature search.

Sen and Chakrabarti's [15] book Sociophysics: An Introduction consists of 8 chapters. The book generally examines the physical aspects of social systems, building on models of known physical systems and discussing the possible applications of statistical physics tools in social systems. Topics such as social choices, popularity, and crowd dynamics were analyzed in detail.

Galam [61] examined the possibility of reshaping the geometry of vision dynamics using the sequential opinion dynamics model. According to this model, the specific parameters of pairwise interactions and inflexible or recalcitrant agents are emphasized. This study offers a new and counter-intuitive perspective on the design of winning strategies in public issues. However, the findings raise ethical issues. In particular, global warming is considered.

Drye [67] explained how the application of sociophysics sheds light on analyzing the comic relief supporter database. This approach allows consistently addressing the consequences of marketing influence at the audience, individual, and social levels. The identified transition occurs at a supporter penetration level of around 1% and relates this characteristic to the connection thresholds between supporters, which provides recommendations for marketing strategies that can be adopted.

Galam [62] studied and analyzed Trump's success according to a model of opinion dynamics from sociophysics. The study utilizes local majority rule arguments. The relevant turning points were found to depend on the social group's

antecedent collective beliefs, cognitive biases, and prejudices. In this way, Trump's success was predictable from the outset.
Ghosh et al. [68] examined some findings on human sociality in contemporary technosocial networks. They focused on observations by analyzing data on billions of searches and text messages from millions of users in a European country over one year. The basic structure of the network and the influence of demographic factors such as age and gender on users' communication patterns on human sociality were evaluated.

Kauffman et al. [69] developed an approach that uses the tools of statistical mechanics to focus on real-world problems and understand the dynamics of social conflicts over time. According to the study, social conflicts are within complex systems and are themselves complex and, therefore, unpredictable. To deal with this uncertainty, planners and decision-makers use a scenario-based anticipation approach rather than forecasting. The use of physics tools can be useful to help parties in such uncertain environments by asking "what if" questions and being prepared for various outcomes.

Capraro and Perc [70] evaluated the statistical physics methods used to study the evolution of cooperation in social dead-end games to show that they encompass a broader spectrum of moral behavior. Inspired by the empirical findings, a roadmap for studying other forms of moral behavior using statistical physics methods was drawn in this context. This study offers a potential direction that can contribute to future research to answer fundamental questions of human social life.

Bhattacharya et al. [71] considered that adopting technologies that facilitate human communication greatly influences people's behavior and social relations. The digital traces of these technologies on different databases have become an active area of research. In particular, data analysis and modeling studies on mobile phone datasets have been conducted from a sociophysics perspective to understand various aspects of human social interactions, such as communication bursts, mobility patterns, and daily rhythms.

Perc [34] reports that more than two centuries ago, Henri de Saint-Simon envisioned the laws of physics to describe human societies, and with advances in statistical physics, network science, data analysis, and information technology, this vision has become a reality. As many of today's biggest challenges are societal, the study argues that physics methods play a central role in advancing understanding of these challenges and helping us find innovative solutions.

Kaufman et al. [72] investigated the application of statistical physics techniques to multi-group social conflicts. In the study, real conflict situations were described, and their model-compatible features were identified. The scenarios generated by the model were used to inform conflict research and management strategies.

Ellero et al. [73] considered a model describing information diffusion, a stochastic model reported in sociophysics. This general model was extended with Linear Programming (LP) formulations that combine social dynamics and information diffusion. This approach formally unifies the stochastic model with the linear programming framework.

Ishii et al. [74] simulated the effects of mass media and used a new theory of opinion dynamics that incorporates trust and distrust in human relationships. They calculated the case where the media works uniformly for the people of society and the case of micro-targeting, where the media works only for those with weak opinions. In addition, the study also calculated the influence of the mass media in directing people toward a particular opinion.

Tanimoto's [75] 12-chapter book presents the essence of evolutionary game theory. Vital epidemiological sociophysical analyses have been applied in the wake of the global COVID-19 pandemic. Its main purpose is to provide a powerful tool when modeling the spread of infectious disease and human decision dynamics during a pandemic. The combination of evolutionary game theory and mathematical epidemiological models addresses various practical issues related to vaccination strategies, such as mask use, quarantine policies, and the effectiveness of vaccination subsidies.

Jusup et al. [18] note that the last decade has seen an increase in the use of physics methods in studying social phenomena, reflecting an interdisciplinary collaboration. The study focuses on topics such as urban development, the functioning of financial markets, cooperation, and the structure of social networks and highlights promising areas for future research. They emphasize that sociophysics plays an important role in understanding social phenomena and the importance of collaboration between scientists.

Kutner [76] has covered milestones in econophysics and sociophysics, emphasizing the importance of these fields in the context of contemporary socioeconomic challenges. In particular, topics such as complexity, network theory, phase transitions, and agent-based modeling were reviewed, and elements of modern sociophysics relevant to addressing risks in financial markets were discussed.

In his work, Yukalov [22] introduces the study of social systems from a physical approach and presents the basic definitions and concepts used to model these systems. A few simple models explained behavior and equilibrium systems were discussed. The work improves readability for non-specialists who want to understand the basics of sociophysics and offers new ideas for experienced researchers.

Dil et al. [77] modeled income data using a q,p-deformed generalization of the Fermi-Dirac distribution. The best-fit parameters were found using the χ^2 minimization routine, and the income distribution was plotted graphically with the obtained deformation parameters. The results show the model's accuracy in systems with high-income inequality and the relationship between r^2 values and the Gini index.

Tsintsaris et al. [78] reviewed sociophysics models and selected applications in social commerce, behavioral finance, and business. The paper discusses three key aspects of social diffusion dynamics: Opinion Dynamics, Group Decision Making, and Information Dynamics. For each category of social diffusion models, noteworthy applications of sociophysics to real-world socioeconomic phenomena were presented, and attention was drawn to issues that hinder the effective application of sociophysics, which is particularly important in modeling assumptions and mathematical formulation.

4. BASIC CONCEPTS, ANALYSIS METHODS AND PRACTICE FOCUS IN SOCIAL PHYSICS

Social physics is a discipline developed to understand and explain human behavior using mathematical and physical models of social systems. In this field, fundamental concepts such as network theory allow the representation and study of relationships between individuals as a network. Complexity theory is important for understanding how societies behave in complex interactions. Furthermore, models such as agent-based modeling are used to uncover the complex behavior of societies by simulating the simple rule-based interactions of individuals. These concepts and theories contribute to understanding human behavior and social structures in social physics [15, 79].

The term "social network" refers to a system of arranging relationships between individuals in a structured way. Family connections, friendships, business relationships, or the exchange of information can often take the form of these relationships. Network analysis is used to understand the complex interaction between social systems by examining the network structure, the individuals involved, the interactions between groups, and the dissemination of information. In social network analysis, the structure, consistency, and centrality of connections are studied to understand the overall composition of the network. An important concept affecting a person's position in the network and ability to interact with others is the extent to which their connections in their social network are significant. A social network also depends on individual cooperation [78, 80-82]. Social network analysis is a tool with practical applications in different fields. For example, it can be used to study customer data or track the spread of disease. Analyzing communication networks can help to understand the organization of channels and the circulation of information. Strategies can be developed to optimize communication processes or speed up the flow of information. These analyses reveal connections and interactions between individuals. It is also used to investigate group dynamics and identify leadership structures. For example, we can monitor information exchange and reactions on Twitter by analyzing users' networks and interactions. This analysis allows us to predict interesting content and the likelihood of popularity of posts on the platform [80, 92, 96].

Social dynamics paints a graphic portrait of a social environment's complex behaviors and complexities. It is a discipline that studies interactions between people, individual relationships, social patterns, and change flows in these processes. In this field, social metamorphosis models based on mathematics and statistics that aim to understand society's patterns are used. They describe the delicate movements and fluctuations that occur within social architecture. Agent-based modeling is an approach that demonstrates the impact of rules that guide individuals' behavior and indicators that illuminate social phenomena. Agents frequently exhibit behaviors that are based on simple rules. These rules guide agents' interactions and relationships with their environment. Agents interact with other agents in their environment and update their behavior because of these interactions. It is particularly useful in studying complex systems because it helps us understand how systems work by modeling the behavior of individual components to understand how complex behavior emerges and changes. It is especially widely used in social physics, economics, biology, and artificial intelligence. Dynamic models in social physics are often realized through computer simulations. These simulations are used to understand the complex behavior of social systems by studying large datasets [15, 19, 38, 72, 83-86].

In social physics, the term 'phase transitions' denotes the transition of a society from one particular state to another. These situations typically alternate between opposing interactions, such as conflict and cooperation. Phase transitions attempt to understand social transformations in social systems. For example, the transition to democratic government and sudden changes in political regimes can be perceived as a transition of period. Economic fluctuations and structural economic changes can be considered as phase transition indicators in such period transitions [15, 60, 87-89].

Data mining enables extracting meaningful information from large data sets. Researchers often use data mining to obtain and analyze large data sets from surveys, social media platforms, and other data sources. Data mining includes techniques such as clustering, classification, exploratory data analysis, and relational analysis [14, 17, 93, 94].

Time series analysis is one of the techniques generally used in social physics research. This analysis technique examines certain parameters' changes, trends, cycles, and seasonal patterns over time. With time series analysis, researchers can explain social events' temporal dynamics and changes [17, 43, 95, 96].

An essential instrument for comprehending and affecting societal processes is social physics. For instance, social physics methods are frequently applied to direct social reform projects or forecast people's behavior in emergencies. Social network analysis is a valuable tool for managing interpersonal connections since it can be used to identify leaders, share information efficiently, and enhance communication. For instance, simulating social behavior can demonstrate the genesis and propagation of large-scale demonstrations or movements. These models have applications in public policy, crisis management, and social change advocacy. Numerous analytical methods are available in social physics to examine how information is used and disseminated in society. Social network analysis, for instance, can be used to comprehend how society reacts to a natural disaster [82, 85].

Game theory is crucial in many disciplines, including business, politics, economics, and strategic planning. In these situations, agent interactions can be modeled and strategic decision-making processes can be directed by social physics. For example, social physicists can use game theory to study how cars behave in traffic. In this instance, traffic congestion resulting from multiple drivers using the same route can be examined using game theory models. Understanding drivers' various route selection tactics and how they affect traffic flow is made simpler by these models. Enhancing traffic control techniques can aid in the reduction of traffic congestion [5, 89, 90].

Vicsek is known for his study in statistical physics and complex systems. The Vicsek model is used to study collective motion in biological systems, such as the flocking behavior of birds or the swimming behavior of fish. The Vicsek model usually refers to mathematical approaches or techniques used to understand and analyze the collective behavior of particles or agents. These approaches usually involve simplified assumptions or numerical methods and aim to capture the fundamental dynamics of interactions between individuals to understand the dynamics of self-organization and pattern formation observed in large groups [97].

The Cellular Automaton is a modeling and simulation technique used in computer science and mathematics. This technique is used to study the computation and change processes that take place on a grid or domain consisting of many simple computational units. It is usually a modeling technique where time and space are discrete, i.e. a grid is updated in certain steps or iterations. When Cellular Automaton is used to model social phenomena, each cell usually represents individuals or a specific group. Using interactions between cells and certain sets of rules, it may be possible to simulate dynamics and behavioral patterns in social phenomena. For example, such models can be used to study public reactions to events such as protests or, widespread acceptance, or information diffusion in social networks [98, 99].

Mean Field Approximation is an analysis method used in statistical mechanics and physics. Especially in complex systems, it can be difficult to directly track all the interactions around each particle. Mean Field Approximation is an approach that averages the total effect of these interactions, thus making the system behavior more simply modellable. This method is often used to understand complex phenomena such as phase transitions, collective behaviors, and statistical properties in many-particle systems. In sociophysics, Mean Field Approximation is used as an important tool to understand collective behaviors and dynamics in social systems. This method offers an approach that models the interactions of many individuals or agents while modeling the effect of each individual on the others [100].

5. CONCLUSION, FUTURE PERSPECTIVES AND CHALLENGES

Social physics is a very valuable tool. Even though researchers continuously conduct studies in this field, social physics requires much more research and investigation. In the future, social physics research is anticipated to grow and become more profound. Emerging technologies, such as big data analysis, network science, and artificial intelligence, are expected to enable a more thorough study of social systems. Integrating these technologies with vast datasets will enable a more profound study and modeling of social interactions and behaviors."
These corrections will enhance the readability and clarity of the manuscript, making it more professional and academically rigorous. As the nature of complex social systems examination is typically uncertain with multiple non-linear relationships, it is exceedingly challenging to build useful and practical models.

Moreover, the ethical aspects of social physics research should be mentioned. Researchers should address the controversial issues of privacy, security, and data protection concerning the employment of technologies. Social physics can help to enhance the comprehension and control of intricate social systems. Therefore, research in this area can contribute to a revolution in the social sciences and solve serious problems in practice.
On the other hand, it has been stated that social physics research can also supply politicians and society members with useful information and attitudes. The findings of sociophysics researchers can benefit policymakers and society members in various ways. Sociophysics' analytical and computational approaches allow for a better understanding of social dynamics. In this way, policymakers can more accurately predict social events and behaviors and develop effective policies. For example, information diffusion and opinion dynamics in society can be modeled using big data analysis and network theory, providing deeper insights beyond opinion polls. It can also provide valuable insights into how societal responses are shaped in times of crisis and which policies can lead to social stability.For members of society, sociophysics can help individuals better understand societal dynamics and the place of their behavior within them. Sociophysics research can explain how information and ideas are disseminated through social media, community events, and other forms of social interaction, how decisions are made within communities, and how these processes can be optimized. In this way, individuals can more consciously evaluate their interactions within social systems and the outcomes of these interactions. Therefore, providing qualitative support, finances, and incentives for social physics research is vital. This can be an essential step towards the society's agenda of justice and equity.

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