

Complex Dynamic Systems Theory for Cognitive Environment Approach

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Abstract - Population Fluctuations (PF), Patch Variation (PV), and Food Webs (FW) are just a few of the areas where the Complex Dynamic Systems Theory (CDST) has made a significant impact on our understanding of the environment. Measures have been used to capture the variation between simple, disordered and ordered frameworks with local interactions that can generate surprising actions on a massive scale. But research shows that conventional explanations of convolution fail to take into account some major characteristics of ecological systems, an ideology that will limit the contributions of CDST to the entire ecosystem. In this paper, we have presented literature review of these characteristics of Environmental Convolution (EC), e.g. diversification, environmental variability, memory and cross-scale interactions, which progress to classical CDST. Advancements in these segments will be essential before CDST can be applicable in the comprehension of more vibrant systems in the environment.

Keywords - Complex Dynamic Systems Theory (CDST), Population Fluctuations (PF), Patch Variation (PV), Food Webs (FW)

I. INTRODUCTION

Complex Dynamic Systems Theory (CDST) involves numerous systems with wide-range elements, which can be social, biological or physical. Provided this form of system diversification, it might be strange to research them under a single model. However, whereas most scientific disciplines are designed to concentrate on the elements themselves, CDST concentrates on the manner in which elements within a single system relate to one another. For example, whereas many disciplines tend to classify systems by columns, CDST class those using rows. Systems are different not due to their variation in their parts, but due to the variation in the manner in which these parts rely on each other. For instance, ice and steam are integrated with water molecules, which are identical; however, because of the variations in the interactions between different molecules have very distinct features. Converse to that, gasses share various behaviors irrespective of the variation in their different constituent molecules. This is typically the case for liquids and solids. The behaviors that differentiate solids from gasses from liquids are samples of emergence; these cannot be determined from the various parts of systems. The turbulence of fluids, as it might be observed in a flowing river, is considered a sample of how the connection between different parts can lead to large-scale patterns and behaviors, which are custom-organized, implying that they arise not from a number of centralized or external controls.

However, it is rather autonomously from the connections between different components of systems. Other samples of custom-organized behaviors integrate the spontaneous creation of the conversation group at the party, the allotment of goods within the disperse economy, the development of environments, and the bird flocking. These significant patterns and behaviors cannot be determined by the assessment of every system segment in isolation. By considering the overall characteristics of systems in general, Complex Systems (CS) provide more interdisciplinary scientific model, which permits for the introduction of novel connections, applications and ideas.

How do we understand a “system?” In essence, it is a surprise that we can comprehend any macroscopic systems as typical mechanical systems integrate trillions of molecules. We are capable of comprehending these systems due to the fact that they possess what is known as “Separation of Scales (SoS)”, which imply microscopic behaviors occur at a far significant scale compared to the behaviors of the custom molecules, with insignificant behaviors happening in between the scales (see Fig 1). The mode of separation permits us to handle the microscopic and macroscopic behaviors distinctively; for mechanical systems, we handle the macroscopic behaviors in an explicitly with Newton mechanisms, whereas a microscopic behaviors is viewed as a cumulative thermodynamics. The SoS means that the actions happening beneath a particular scale are at a large scale mostly independent from one another, and therefore, at a large scale, it is only the mean implication of the small-scale actions that is essential.

In general, the strategy illustrated above is one of the examples of the Mean Field Theory (MFT), whereby the mean behaviors of the systems’ elements are explicitly demonstrated and the deviation of the custom elements from this mean are handled as statistically independent PF in an arbitrary manner. This strategy operates well for the systems like buildings, airplanes, cars and computers, in which the motion of custom individuals are, aside from some

unconnected PFs, we illustrated by the motions of the material pieces to which they are grouped. MFT are also employed in evaluations of economic, social and biological systems; these theories operate effectively in various instances. However, as we shall visualize, they are inappropriate for more CS. It is fundamental, thus, to determine the conditions the MFT holds.

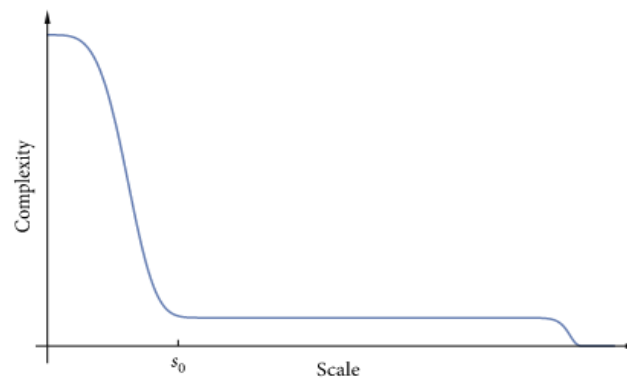


Fig 1. The convolution profile of systems with SoS

According to J. Freeman in [1], there has been an increase in the Environmental Convolution (EC). Recent books, bio-convolution initiatives, national research efforts, and international journals such as EC all reflect this trend. The field applies theories and tools from research in CDST to illustrate and comprehend environmental phenomena. In spite of the growing acceptance of CDST in numerous sectors, environmentalists have yet to incorporate the domain of EC, and it remains controversial to many. As a result of attempts to characterize basic ideas, EC has been represented in a variety of conceptual illustrations throughout the world.

As a complex adaptive system, Environmental Systems (ES) are considered by G. Huang and X. Qin [2] to be the prototypical CAS, where "macroscopic system characteristics, such as trophic structures, productivity-diversification connections, and the pattern of nutrient variation, are introduced by the interaction of different elements, with the potential to influence the initiation and progression of interaction." The CAD strategy like all the CDST strategy focuses on explaining all the environmental aspect with restricted set of constraints and protocols. Even though operational and clear environmentalists have yet to be globally integrate this aspect this aspect within their strategy. We have a belief that hesitancy around CDST is due to the uncertainties about what the strategy brings to the environment. Any novel strategy to learning EC should just suggest novel formalisms and frameworks but also novel interpretation of environmental facets.

In this paper, we highlight the contribution of CDST to three fundamental segments of the ecosystem: Population Fluctuations (PF), Patch Variation (PV) and Food Webs (FW). In analyzing these samples, we present the limitations for the present definitions of EC derived from CDST and recommend novel research directions for enhanced integration between the environment and CDST. This research contribution is arranged as follows: Section II evaluates the relevant works related to EC and CDST. Section III provides a critical analysis of CDST contribution to the environment. Section IV concludes the paper.

II. LITERATURE REVIEW

P. Hiver, A. Al-Hoorie and D. Larsen-Freeman in [3] evaluated the integration of the classical Complex Dynamic Systems Theory (CDST) with the Environmental Convolution (EC). It is believed that the frameworks and measures from the conventional CDST will have limited application for the ecosystem in the upcoming generation because environmentalists' notion of convolution habitually integrates diversification, interrelationship, which crosses various organizational, temporal and spatial scales, historical effects (environmental memory), fluctuating ecosystems and heterogeneous ecosystems. The study illustrates the generic elements of the EC with the samples of the forest environment. The environmental memory signifies a record of the previous events, which might introduce temporary dependencies in the variation of the complex system since it affects its presents and futuristic states.

T. Wachs, J. Morrow and E. Slabach in [4] emphasize the significance of environmental and memory variability since these is the major characteristics of environmental systems, which formulate and maintain diversification (phenotypic and genetic). The aspect of diversification is not just a passive impact of the environmental interaction, but a significant determinant of the adaptability and persistence of the system in the face of ecological transition. Ecological variability is ubiquitous; nonetheless, there have been discussions concerning the priority of external against internal causes of the environmental variability. The synthesis of these two ideas affirms the probability that EC might be produced by the interconnection between the internal custom-organized variation and the variable ecosystem, a perspective notably absent in the standardized illustrations of the CS, which normally eliminates internal (ecological) impacts. A number of these facets of the EC are not accommodated by the present tools and methodology provided by CDST; nonetheless, the emergent research in this field is starting to provide remedies.

F. Liu, R. Wang and L. Wei in [5] evaluated the novel measures – from diversification to convolution. The environmentalists have globally applied data – theoretic illustrations from CDST to evaluate diversification (such as Shannon entropy), but a few of them tried to quantify complexities with respect to other data and coding theoretical illustrations recommended by CDST. The latter that integrate adoption of the perspectives of algorithmic complexities and average data gains, might aid in the integrated concepts e.g. cross-scale change and interactions into static convolution measures. Novel measures have to incorporate the present statistical variance descriptors (invariance) and the order or disorder and be explicitly connected to dynamic environmental perspective e.g. stability and disturbance. A high degree of disorder (unpredictability) and elevated diversification valuation seem at odds with the goal of diversification of predictability (stability) within surroundings, and this could help resolve this.

C. de Oliveira Faria and A. Magrini in [6] also looked at how biodiversity PF, cross-scale interplay, and memories are incorporated into the performance impacts, as well as some of the primary criticisms of the intricacies. This is still a problem in the ecosystem, however. If the species segment curve and species abundance distribution are scale-invariant, then different diversification indices can be connected to them via inter reviews. In the same way, incorporation of spatial variability and classic disorder-centered diversification in the convolution measure has been indicated to capture the cross-scale pattern.

Š. Schwarz in [7] have introduced the convolution measures to classify the available boundary between the disordered and ordered stages (in randomized Boolean network), which integrates variance. This strategy might provide a remedy to the calls for interconnectivity measures meant to integrate the matrix implications (spatio-temporary heterogeneity) on land – scale and Meta – populace convolution. A fundamental convolution measure reflected the diversification variation (variation entropy), which explicitly evaluate the connection between stability, perturbation, convolution and diversification has been proposed over the past few decades. A novel measure established in the hierarchy theory identifies that the highest dimensions of convolution happen at the intermediate integration dimension and lower perturbation levels.

O. Bastian and M. Lütz in [8] analyzed various indicators, incorporating enhancing variance and enhancing autocorrelations in the major system variables before their collapse. Novel measure that attempt to incorporate variability and disturbance, into the classical convolution measures, will be of certain diagnostic value in the analysis of international environmental transition. Moreover, strategies that provide more comprehension on the connections between static (structural) and dynamic convolution will be fundamental.

III. CRITICAL ANALYSIS

Simplified Frameworks and Measures

Significant differences exist in convolution definitions and measurements as a result of convolution's relative infancy as a scientific field. This belief is reflected in many definitions, which are derived from data theory and reflect the belief that systems are complex whenever they include multiple parts whose combined behavior or state can be difficult to predict. The definitions therefore assign a high dimension of convolution to arbitrary states. Data theoretic concepts include efficient complexities, which focus on the dimension of regularity, rather than the arbitrariness highlighted by systems; computational complexities of various types (time, grammatical, Kolmogorov, and algorithmic convolution), which all focus on the effort required to represent systems; and mutual data – the dimension in which systems' states of element interact with one another.

Convolution measures often begin with two extents of organized and subjective states, with elevated computation arising anywhere in between (see Fig 2). The states of convolution could also be illustrated by statistical scaling connections e.g. power laws or fractal dimension. Simplified measures like these could be utilized to differentiate homogeneous or arbitrary environment pattern from more complex ones and might act as diagnostic frameworks to identify transitions in the states of the environment. Fig 2 represents the structural, spatial and temporal signatures of simplified disordered and ordered systems against the more CS.

- Sinusoidal time series – Organized spatial pattern, systematic network;
- Population Variation (PV) of the modeled plant species from custom-centered model – Spatial supply of the preys within the frameworks of the Lotka Volterra with diffusion on the coupled lattice of the map (generated with a model), networks (free scale) of the different Food Webs (FW);
- Random disseminated chaos – Random spatial dissemination, random networks.

This column (rightmost) shows the schema of the bandwidth assessment for each case. While the confidence interval in conceptual signature verification is always evaluated, it could also be used to assess the patch distribution and measurements in spatial signatures, or even the connectivity distribution in each network node, depending on the application. Whereas these static interpretations and batch normalization measures are integral, they do not tell us how more intricate perspectives are evident when they are not. There are null frameworks that can be used to identify these convolution structures and patterns. It's also possible to predict multiple environmental patterns using neutral theories. Nonetheless, the CDST application to the ecosystem necessitates that more complex structures differentiate arbitrary from non-arbitrary ecological procedures. Fig. 1c and 1b can be compared to see if there are any structural, computational, and temporal signatures that can be seen in the final column.

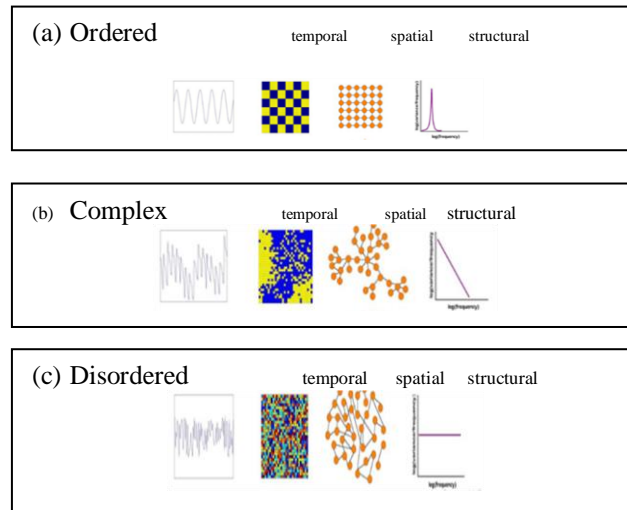


Fig 2. The structural, spatial and temporal signatures of simplified disordered and ordered systems against the more CS

Because of this, structures and patterns that emerge from non-arbitrary processes are important to CDST. This directs to another significant contribution of CDST to the environment; the observations that simpler frameworks, with particular major non-arbitrary characteristics, could generate more complex variation and structures. Environmentalists have embraced this based on the modeling of the ecosystem as a simple system of particulars that interact often (such as species, agents, and individuals, typically in comprehensive, unchanging spatial and temporary ecosystems). The application of simplified frameworks can enhance our comprehension of environmental variation and the mechanistic origin of more observable patterns.

By highlighting the significance of regionalized interplaying particles, CDST structures have been able to explain a variety of remarkable infrastructural trends in history. The paragraphs below focus on explaining how simplified frameworks and measures from CDST have enhanced our understanding in three fundamental segments of the environment: PF, PV and FW.

Population Fluctuations (PF)

The classic query in the populace ecosystem of the impacts of the density dependencies and of the ecological PFs on the regulation of the populace has significantly benefited by the analysis of CDST. The series of time of the populace variation were evaluated recently for signatures of the environmental complexities. They have sought to determine as to if "more time" symbolizes "more variants" in the population's densities, and this is power signature law interdependence between the variability and recurrence of variability within the population. There are specific differences in how the power (variance) of the population fluctuates with respect to the frequency (f). The low-frequency dominance creates a population series with high variance and a long time span.

In a research of 544 deep population data series, L. Molinari in [9] calculated as the proportion of spectroscopic derivations based on the median value (1.0) reveals that certain economies have $1/f$ variations. The $1/f$ PF, in which beta equals one, has received a lot of attention in CDST because it indicates scale invariance, which is common in wide-range complex aspects like stage transitions, which are known for their PFs that typically decay as the power law. However, the identification of $1/f$ PF is non-equilibrium system, e.g. the populace, is not a proof for particular framework of how the globe operates, for instance, the custom – organized criticality. Nevertheless, the global case of $1/f$ PF of the populace is a genuine concern of the populace experts since it pertains to the long – term problem of populace regulations as well as density dependencies.

Standard environmental frameworks centered on the logistic development recommend a tight density stationarity and regulations in the variance and mean of densities within the populace. The $1/f$ pattern in populace abundance signifies the evidence against stationarity and simplified perspective of the populace regulations within the fluctuating ecosystem. As a further point to note, it has been shown that higher frequency PFs dominate the noise variation energy spectrums produced by the classic populace frameworks (blue spectrums), which are in direct conflict with the time series evaluations. In attempt to comprehend the consequences of PFs on inhabitants, they were expected to focus on this evident discrepancy between the emission spectra of socioeconomic data series and those generated by standard population structures.

Various adjustments of the standardized populace frameworks were recommended to formulate a stronger minimum frequency variation (red spectra) within the variation. On account of a delay in density dependence on PV, stabilising the high frequency variations in density could indeed boost PV. Take, for instance, other options include spatially explicit meta-populations where local dispersals could increase the population's variability. In this case, local dispersals slow the influence or propagation of the native community so that low-frequency variants take control.

CDST methodology's theoretical findings and developments are a direct result of the population's time series evaluation. Even though $1/f$ variation is not new to environmental schemes, incorporating CDST instruments and approaches may make it easier for environmentalists in general to deal with and provide more alternative definitions for remarkable perspectives.

Patch Variation (PV)

Based on the application of the life history tradeoffs between the competition capacities and growth rate capacities, it might be easier to maintain and enhance diversification. This is the forecast of the hypothesis for the intermediate disturbance that was initially established as a spatial and homogeneous theoretical assumption. Contrast to the theoretical assumptions that assume “mixed” distraction, the PV forecast the diversification of species based on the size and intensity of the novel gaps. It accurately permits dispersal limitations to mediate the co-existence of species. Because of the separation of the scales between population development and physical distractions in different environments, its application in the environment is based on the PV theory.

Nevertheless, various distracted systems, integrating forest fires, incorporate local and direct responses between recovery and disturbance. CDST is applicable in these scenarios based on the application of the dynamic frameworks, which define the various procedures at scales closer to beings. These frameworks contrast with the initial patch dynamic frameworks by illustrating the procedures of distraction and recovery of the neighbors and explicit. Significantly, these frameworks conform to the overall model of CDST by identifying the possibilities for these localized procedures to define and produce macroscopic features of the distracted environmental systems.

Actually, CDST frameworks of distraction variation forecast the custom-organization of the wide-range connection between distance persons, supported by the power law (scale invariant) frequency distribution of the patch dimensions. Wide-range characteristics of distraction regime become forecasts, which are entirely centered on local rates and the geometries of recovery and disturbance. From the type of threshold feedback to the biological and ecological conditions, one fundamental effect can be identified. Some tropical forests can have their scale-invariant frequency distribution predicted by simile domino implication of the wind, a process that mimics interactions between different particles in the physical system. The Rocky intertidal societies provide more samples in this case.

CDST has therefore amounted to useful and distinct theory of distraction variation linked to the testable forecasts, which could still be connected to the PV. Nonetheless, interlinked data with particular frameworks is still a prevailing concern. The issue originates from the ideology that scale invariant distribution has an alternative implication that does not support the scale invariant as the signature of the custom-organization. The sensitivity aspect of the simple CDST framework to species interaction and to ecological PFs is widely unknown.

Food Webs (FW)

The theoretical assumption about the FW have initially stressed on the research of convolution and stability based on the structures of the trophic interaction. Recent studies in the graph networks and theories have indicated that various CS have the same structural characteristics. For instance, human-created, biological and diverse physical systems have all indicated the scale-invariant structures whereby the network is typically arranged around different massive hubs with various less-linked nodes. In addition to being resistant to the loss of system elements, this type of structure is also more resistant to rapid changes in the node features, implying stability, which is important for environmental research and biodiversity.

As a result of the shift in quantitative approaches used to evaluate complex networks, concerns about FW structures have returned, resulting in a re-evaluation of some of the most famous data sets. Although FWs have complex, non-arbitrary systems, investigations on rate dispersion (the allocation of the interconnections for each base station) and topological features have shown that they do. Innovating analytic methods have allowed environmental activists to define main aspects of FW systems, such as communities of intimately organisms and co-extinction structures. These findings are re-stimulating the discussions on whether environmental societies assemble towards the structure, which favors dynamic stability and persistence.

When it comes to FW structure, CDST's novel dynamic PV analysis has provided new insights into how the FW structure changes and assembles. These frameworks reproduce various facets witnesses in empirical research e.g. power laws scaling in species and the closure of events, non-arbitrary (however non-scale free) networking structures and the shorter lengths of the food chain. Justly like the contemporary Lotka Volterra format populace frameworks; these frameworks handle the FWs as larger developing network systems whereas every species represents nodes which dimensions of population change as the characteristics of the interdependence with other organisms [10].

Dense FW structures are dynamically shifted by these novel frameworks, which are based on more recent evolutionary computing approaches. The digital genome is used to represent species in these frameworks. The development of species genomes is enabled by low mutation rates during reproduction, allowing the species to adapt to its interaction vitality and parameters effectively and efficiently. These dynamic frameworks tend to produce spatial and temporary data concerning the interactions on the webs over several generations that could be challenging or difficult to evaluate in the group, amounting to the production of a novel hypothesis concerning the manner in which the environmental society are assembled and structured over time. Adding to the formation of novel platforms of study in the ecosystem, e.g. the researches of species formation and evolution of environmental societies, these frameworks might allow environmentalists to establish parallels between the complex biological systems and the variation of the environmental networks (such as the biochemical and neuronal networks).

*Contemporary Study**Objective of Memory*

Environmental memory is stimulated by the capability of the contemporary states to motivate the current and futuristic feedbacks on the environmental systems. The samples incorporate the seed banks, diapause eggs and the presence of the rare species within the environment, which might signify the records of the part development or the inversion of species. Distractions (draught or fires) might form more persistent patterns at the wider scales, which might entrain the futuristic processes within the ecosystem. Memory signifies that the system might draw upon the previous events inform of the present or upcoming behaviors; this is normally the characteristic of individual beings. According to recent research, individuals can improve their fitness by referring to their previous prey distribution or amount when foraging, as an example [11].

Based on the perspective of the observer, memory is established by a rigid temporal dependency of the environmental system variation. The modeling memory-centered system could be attained through the integration, correlation or the timelag into the framework structure. However, it is still a major concern that has to be addressed in various CDST frameworks. The development in individual-based frameworks is to integrate memory through the agents in order to make forecasts based on previous data; such forecasts might be cue-centered and fundamental to various ecological schemes, or might permit agent actions to be heritable or adaptive stimulating evolution. These approaches might redefine the phenomena of CS where more local interaction depends on the recorded previous events to effectively operate across multiple spatial and temporary scales [12].

Complex Implications of Ecological Variability

Despite the fact that environmental systems have been subjected to constant ecological variations, many CDST frameworks used in the environment do not consider their ramifications. Two fundamental queries are considered: To what degree are the findings from the CDST framework of community and populace variation rich to the ecological variability? Can the interactions of CDST with the variable ecosystems amount to new variation? The best example of the significance of these queries is shown in researches about complex spatially variation of the parasitoid existence. The formulation of the parasitoid engagement is significantly unstable within the spaces that are homogeneous. It is shown that host parasitoid persistence is likely by applying the attached map lattice formalisms whereby various patches are linked through diffusion dispersal. The variation provides more complex patterns such as drifts, discord and particle lattice structures, which are integral for ingenuity.

If the host increase rate is treated as a white chaos, coexistence has a high degree of ecological variability. The ecological variation did not affect the co-existence (spatial patterns) if it happened at a small-scale compared to being large-scale. No matter how large an ecological variation becomes, the spatial pattern does not change. If other types of ecological variability (such as coloured chaos) affected or strengthened this assumption, it was not considered. At some point, CDST will have to do explicit research on the impact of realistic ecological features on environmental variation in the future. Researchers found that ecological chaos affected the FW's stability by causing population oscillations that were complex in terms of linkage, synchrony, and magnitude.

As part of their study, researchers looked at how the cornerstone FW (a dynamic configuration of the predator that consumes two different species of prey in competition for shared resources) changed over time within the meta-society to better understand the interplay between ecological variability and regional and local FW stability. Irrespective of the rate of dispersal, stringent ecological PF affected the compensatory variation of the prey and diminished the stability aspect by inducing sporadic correlated changes between the preys within the local FW. Other works have recommended that the prompt collapse of the environmental systems is considered to rise out of the non-linear biotic feedback to minimize the ecological transitions. Minimal environmental theory has appealed the interactions between the ecosystem and custom-organization to illustrate the collapse variation, but researches recommend that the transitions of the custom-organized patterns of vegetation might foretell immediate transition in aquatic and arid environments.

In physical sciences, forecasting the systems' failures under stress e.g. earthquakes and rupture is still a significant scientific concern. Complex (periodic) scaling exponents are a feature of complex (recurring) scalability exponential function (such as log periodicities). For example, it can be used to predict whether or not simple and local interactions will cause catastrophic events (such as massive amplitude) and the collapse of globalized systems. Log periodicities have, over the past few decades, been used in forest fires and collapse variation might be utilized to insect or disease outbreaks, desertification and wildfires.

Ecological heterogeneity in space and time has been shown to be important in predicting the spread and onset of forest fires according to empirical research. This heterogeneity is not a just problematic on the validity of simplistic CDST frameworks, but necessitates that we focus on the cross-scale responses between custom-organized features and the ecosystem. Localized connections and custom-organized tree clustering can drive fire propagations but a particular threshold dimension; fires begin to impact the conditions of weather, which can therefore fire propagations, amounting to more positive response. There are multiple thresholds that can be identified in the physical system that define the apparent time and space discontinuity. Experimental and theoretical evidence shows that ecological variability can provide CDST with synergistic hypotheses, rather than competing ones.

IV. CONCLUSION

Physical systems are either arbitrary or predictable in nature. Nonetheless, environmental systems have more stochastic or substantial elements and worthwhile element that is predictable and this is typically masked by the stochastic one that makes it problematic to research. Mitigating this issue has necessitated theoretical comprehension, which employs computational, statistical and mathematical phenomena whereby the concepts of arbitrariness and determinism, typically considered as an independent procedures, are entwined. Deterministic noise is a classic example of how these aspects are intertwined. A paradigm gap exists in recognizing the selectivity reliance on initial state, which impacts long-term uncertainty in more complicated systems, such as geographical factors. It is also possible to create a custom-organized criticality that uses simple computational protocols to illustrate dramatic regime transitions within the system. As fractal levels are increasingly used in CS, they are primarily used to define temporal structures, which can be found in ecological variables but cannot be ascertained by Geometric metrics. Whereas rich theories and instruments have emerged rapidly over the past few decades, environmental complexities could be completely researched using the present methodologies and definitions provided by CDST. There is a significant potential for CDST development through the evaluation of characteristics of environmental systems, which render them distinct (cross-scale interaction, memory, diversification, and understanding of ecological unpredictability). To improve prediction and understanding, environmentalists still need to identify generalizations in the systems' variation and patterns. As a result, CDST is well-versed in identifying these generalizations within distinct CS subcategories

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