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Chapter 1 : Logistic map - Wikipedia

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Chapter 2 : Chaos in Ecology: Experimental Nonlinear Dynamics (Theoretical Ecology Series) - Ebook pdf

Preface An Experimental Approach to Nonlinear Dynamics and Chaos is a textbook and a refer-ence work designed for advanced undergraduate and beginning graduate students.

By varying the parameter r, the following behavior is observed: With r between 0 and 1, the population will eventually die, independent of the initial population. These two values are dependent on r. With r between 3. With r increasing beyond 3. This behavior is an example of a period-doubling cascade. From almost all initial conditions, we no longer see oscillations of finite period. Slight variations in the initial population yield dramatically different results over time, a prime characteristic of chaos. Most values of r beyond 3. The development of the chaotic behavior of the logistic sequence as the parameter r varies from approximately 3. Such a scenario has an application in semiconductor devices. A period-doubling window with parameter c is a range of r-values consisting of a succession of subranges. The kth subrange contains the values of r for which there is a stable cycle a cycle that attracts a set of initial points of unit measure of period 2kc. This sequence of sub-ranges is called a cascade of harmonics. The r value at the end of the infinite sequence of sub-ranges is called the point of accumulation of the cascade of harmonics. As r rises there is a succession of new windows with different c values. For any value of r there is at most one stable cycle. If a stable cycle exists, it is globally stable, attracting almost all points. The bifurcation diagram at right summarizes this. The horizontal axis shows the possible values of the parameter r while the vertical axis shows the set of values of x visited asymptotically from almost all initial conditions by the iterates of the logistic equation with that r value. Bifurcation diagram for the logistic map. The attractor for any value of the parameter r is shown on the vertical line at that r. The bifurcation diagram is a self-similar: The same is true for all other non-chaotic points. This is an example of the deep and ubiquitous connection between chaos and fractals. For example, for any initial value on the horizontal axis, f4 gives the value of the iterate four iterations later. The relative simplicity of the logistic map makes it a widely used point of entry into a consideration of the concept of chaos. In the case of the logistic map, the quadratic difference equation describing it may be thought of as a stretching-and-folding operation on the interval 0,1. However, we can embed the same sequence in a three-dimensional state space, in order to investigate the deeper structure of the map. Figure b , right, demonstrates this, showing how initially nearby points begin to diverge, particularly in those regions of xt corresponding to the steeper sections of the plot. This stretching-and-folding does not just produce a gradual divergence of the sequences of iterates, but an exponential divergence see Lyapunov exponents , evidenced also by the complexity and unpredictability of the chaotic logistic map. In fact, exponential divergence of sequences of iterates explains the connection between chaos and unpredictability: Hence, predictions about future states become progressively indeed, exponentially worse when there are even very small errors in our knowledge of the initial state. This quality of unpredictability and apparent randomness led the logistic map equation to be used as a pseudo-random number generator in early computers. It can be shown that the correlation dimension is certainly between 0. It is often possible, however, to make precise and accurate statements about the likelihood of a future state in a chaotic system. If a possibly chaotic dynamical system has an attractor , then there exists a probability measure that gives the long-run proportion of time spent by the system in the various regions of the attractor. Specifically, [10] the invariant measure is 1.

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Chapter 3 : Nonlinear dynamics and chaos

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Chapter 4 : Chaos theory | Psychology Wiki | FANDOM powered by Wikia

An Experimental Approach to Nonlinear Dynamics and Chaos by Nicholas B Tufillaro, Tyler Abbott, Jeremiah P Reilly starting at $ An Experimental Approach to Nonlinear Dynamics and Chaos has 1 available editions to buy at Alibris.

Show Context Citation Context The key concept for describing chaotic time series is a chaotic attractor. Let M be a manifold a smooth geometric space such as a line, smooth surface or solid [30, p. Povinelli , " The TSDM framework adapts and innovates data mining concepts to analyzing time series data. In particular, it creates a set of methods that reveal hidden temporal patterns that are characteristi In particular, it creates a set of methods that reveal hidden temporal patterns that are characteristic and predictive of time series events. This contrasts with other time series analysis techniques, which typically characterize and predict all observations. Finally, the TSDM method is applied to time series generated by a basket of financial securities. The results show that statistically significant temporal patterns that are both characteristic and predictive of events in financial time series can be identified. TSDM-based methods can successfully characterize and p Only recently was it discovered that SLIP possesses some degree of p Only recently was it discovered that SLIP possesses some degree of passive stability. In this research, the possibility of the realization of the SLIP model is investigated first in numerical simulation. Next, a small one-legged hopping robot with only one actuator is designed and built, and a simple hopping controller is implemented, which results in running with approximately 0. Comparison between simulation and experimental data is undertaken, and the stability of the resulting motion is investigated. First of all, I thank the people who gave me the chance: I thank for their understanding and support. He encouraged my plan to study abroad. It is also called stride function [25] or return map [73], [45], [62] in legged locomotion. It is a discrete map created from a continuous dynamics or from a combination of several continuous dynami General features of stability domains for time--delayed feedback control exist, which can be predicted analytically. We clarify, why the control scheme with a single delay term can only stabilise orbits with short periods or small Lyapunov exponents, and derive a quantitative estimate. The limitation can be relaxed by employing multiple delay terms. In particular, the extended time delay autosynchronisation method is investigated in detail. Analytic calculations are in good agreement with results of numerical simulations and with experimental data from a nonlinear diode resonator. Chaos control, Pyragas method, Differential--difference equation 1 Introduction Controlling the motion of dynamical systems is one of the classical subjects in engineering and mathematical science. Sophisticated tools have been developed for that purpose cf. Within the last decade such topics have attracted the interest of many physicists in the context of nonlinear dynamics since th From template analysis to generating partitions I: We present a detailed algorithm to construct symbolic encodings for chaotic attractors of three-dimensional flows. It is based on a topological analysis of unstable periodic orbits embedded in the attractor and follows the approach proposed by Lefranc et al. For each orbit, the symbolic names that are consistent with its knot-theoretic invariants and with the topological structure of the attractor are first obtained using template analysis. This information and the locations of the periodic orbits in the section plane are then used to construct a generating partition by means of triangulations. We provide numerical evidence of the validity of this method by applying it successfully to sets of more than periodic orbits extracted from numerical simulations, and obtain partitions whose border is localized with a precision of 0. A distinctive advantage of this approach is that the solution is progressively refined using higher-period orbits, which makes it robust to noise, and suitable for analyzing experimental time series. Furthermore, the resulting encodings are by construction consistent in the corresponding limits with those rigorously known for both one-dimensional and hyperbolic maps. In the case of reversi Parametric identification of a chaotic base-excited double pendulum experiment by Y. Feeny - Nonlinear Dynamics " The improved parametric identification of chaotic systems was investigated for the double pendulum system. From recorded experimental response data, the unstable periodic orbits were extracted and later used in a harmonic balance identification process. By applying digital filtering, digital differe By applying digital filtering, digital differentiation and linear regression techniques for optimization, the results were improved. Verification of the related simulation system and linearized system also corroborated the success of the identification algorithm. Fractional derivatives are applied in the reconstruction, from a single observable, of the dynamics of a Duffing oscillator and a two-well experiment. The fractional derivatives of time series data are obtained in the frequency domain. The derivative fraction is evaluated using the average mutual in The derivative fraction is evaluated using the average mutual information between the observable and its fractional derivative. The ability of this reconstruction method to unfold the data is assessed by the method of global false nearest neighbors. The reconstructed data is used to compute recurrences and fractal dimensions. The reconstruction is compared to the true phase space and the delay reconstruction in order to assess the reconstruction parameters and the quality of results. The simulation generated data with a samplin From template analysis to generating partitions II: We give numerical evidence of the validity of a previously described algorithm for constructing symbolic encodings of chaotic attractors from a template analysis. We verify that the different solutions that can be found are dynamically equivalent, and that our approach yields results that are consis We verify that the different solutions that can be found are dynamically equivalent, and that our approach yields results that are consistent with those obtained from methods based on homoclinic tangencies. This is further confirmed by verifying directly that the computed partitions are generating to a high degree of accuracy, and that they can be used to estimate precisely the metric entropy. It is also shown that the correct number of symbols needed to describe the dynamics is naturally provided, and that a compact parameterization of a partition can easily be determined, Powered by:

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Chapter 5 : CiteSeerX â€" Citation Query An experimental approach to nonlinear dynamics and chaos

The course will introduce the students to the basic concepts of nonlinear physics, dynamical system theory, and chaos. These concepts will be demonstrated using simple fundamental model systems based on ordinary differential equations and some discrete maps.

Edit Chaotic behavior has been observed in the laboratory in a variety of systems including electrical circuits , lasers , oscillating chemical reactions , fluid dynamics , and mechanical and magneto-mechanical devices. Observations of chaotic behaviour in nature include the dynamics of satellites in the solar system , the time evolution of the magnetic field of celestial bodies , population growth in ecology , the dynamics of the action potentials in neurons, and molecular vibrations. Everyday examples of chaotic systems include weather and climate. A related field of physics called quantum chaos theory studies systems that follow the laws of quantum mechanics. Recently, another field, called relativistic chaos , [5] has emerged to describe systems that follow the laws of general relativity. As well as being orderly in the sense of being deterministic, chaotic systems usually have well defined statistics. For example, the Lorenz system pictured is chaotic, but has a clearly defined structure. Bounded chaos is a useful term for describing models of disorder. Much of the early theory was developed almost entirely by mathematicians, under the name of ergodic theory. Later studies, also on the topic of nonlinear differential equations, were carried out by G. Littlewood , and Stephen Smale. Except for Smale, these studies were all directly inspired by physics: Although chaotic planetary motion had not been observed, experimentalists had encountered turbulence in fluid motion and nonperiodic oscillation in radio circuits without the benefit of a theory to explain what they were seeing. Despite initial insights in the first half of the century, chaos theory became formalized as such only after mid-century, when it first became evident for some scientists that linear theory , the prevailing system theory at that time, simply could not explain the observed behaviour of certain experiments like that of the logistic map. What had been beforehand excluded as measure imprecision and simple " noise " was considered by chaos theories as a full component of the studied systems. The main catalyst for the development of chaos theory was the electronic computer. Much of the mathematics of chaos theory involves the repeated iteration of simple mathematical formulas, which would be impractical to do by hand. Electronic computers made these repeated calculations practical, while figures and images made it possible to visualize these systems. One of the earliest electronic digital computers, ENIAC , was used to run simple weather forecasting models. He wanted to see a sequence of data again and to save time he started the simulation in the middle of its course. He was able to do this by entering a printout of the data corresponding to conditions in the middle of his simulation which he had calculated last time. To his surprise the weather that the machine began to predict was completely different from the weather calculated before. Lorenz tracked this down to the computer printout. The printout rounded variables off to a 3-digit number, but the computer worked with 6-digit numbers. This difference is tiny and the consensus at the time would have been that it should have had practically no effect. However Lorenz had discovered that small changes in initial conditions produced large changes in the long-term outcome. The year before, Benoit Mandelbrot found recurring patterns at every scale in data on cotton prices. Beforehand, he had studied information theory and concluded noise was patterned like a Cantor set: Mandelbrot described both the Noah effect in which sudden discontinuous changes can occur, e. Arguing that a ball of twine appears to be 1-dimensional far , 3-dimensional fairly near , or 1-dimensional close , he argued that the dimensions of an object are relative to the observer and may be fractional. In Mandelbrot published The Fractal Geometry of Nature , which became a classic of chaos theory. Biological systems such as the branching of the circulatory and bronchial systems proved to fit a fractal model. Yoshisuke Ueda independently identified a chaotic phenomenon as such by using an analog computer on November 27, The chaos exhibited by an analog computer is a real phenomenon, in contrast with those that digital computers calculate, which has a different kind of limit on precision. Doyne Farmer and Norman Packard who tried to find a mathematical method to beat roulette , and then created with them the Dynamical Systems Collective in Santa Cruz , and the meteorologist Edward Lorenz. The following year, Mitchell Feigenbaum published the noted article "Quantitative Universality for a Class of Nonlinear Transformations", where he described logistic maps. Feigenbaum had applied fractal geometry to the study of natural forms such as coastlines. Feigenbaum notably discovered the universality in chaos, permitting an application of chaos theory to many different phenomena. In , Albert J. Libchaber during a symposium organized in Aspen by Pierre Hohenberg his experimental observation of the bifurcation cascade that leads to chaos and turbulence in convective Rayleigh-Benard systems. Feigenbaum "for his brilliant experimental demonstration of the transition to turbulence and chaos in dynamical systems". Bernardo Huberman thereby presented a mathematical model of the eye tracking disorder among schizophrenics [7]. Chaos theory thereafter renewed physiology in the s, for example in the study of pathological cardiac cycles. In , Per Bak , Chao Tang and Kurt Wiesenfeld published a paper in Physical Review Letters describing for the first time self-organized criticality SOC , considered to be one of the mechanisms by which complexity arises in nature. Alongside largely lab-based approaches such as the Bak-Tang-Wiesenfeld sandpile , many other investigations have centred around large-scale natural or social systems that are known or suspected to display scale-invariant behaviour. Although these approaches were not always welcomed at least initially by specialists in the subjects examined, SOC has nevertheless become established as a strong candidate for explaining a number of natural phenomena, including: Worryingly, given the implications of a scale-free distribution of event sizes, some researchers have suggested that another phenomenon that should be considered an example of SOC is the occurrence of wars. The same year, James Gleick published Chaos: Making a New Science , which became a best-seller and introduced general principles of chaos theory as well as its history to the broad public. At first the domains of work of a few, isolated individuals, chaos theory progressively emerged as a transdisciplinary and institutional discipline, mainly under the name of nonlinear systems analysis. The availability of cheaper, more powerful computers broadens the applicability of chaos theory. Currently, chaos theory continues to be a very active area of research, involving many different disciplines mathematics, topology , physics, population biology, biology, meteorology, astrophysics, information theory , etc. Chaotic dynamics For a dynamical system to be classified as chaotic, it must have the following properties: Sensitivity to initial conditions means that each point in such a system is arbitrarily closely approximated by other points with significantly different future trajectories. Thus, an arbitrarily small perturbation of the current trajectory may lead to significantly different future behaviour. Sensitivity to initial conditions is popularly known as the " butterfly effect ", so called because of the title of a paper given by Edward Lorenz in to the American Association for the Advancement of Science in Washington, D. The flapping wing represents a small change in the initial condition of the system, which causes a chain of events leading to large-scale phenomena. Had the butterfly not flapped its wings, the trajectory of the system might have been vastly different. Sensitivity to initial conditions is often confused with chaos in popular accounts. It can also be a subtle property, since it depends on a choice of metric, or the notion of distance in the phase space of the system. For example, consider the simple dynamical system produced by repeatedly doubling an initial value defined by the mapping on the real line from x to 2x. This system has sensitive dependence on initial conditions everywhere, since any pair of nearby points will eventually become widely separated. However, it has extremely simple behaviour, as all points except 0 tend to infinity. If instead we use the bounded metric on the line obtained by adding the point at infinity and viewing the result as a circle, the system no longer is sensitive to initial conditions. For this reason, in defining chaos, attention is normally restricted to systems with bounded metrics, or closed, bounded invariant subsets of unbounded systems. Even for bounded systems, sensitivity to initial conditions is not identical with chaos. Because of the doubling in the first coordinate, the mapping exhibits sensitive dependence on initial conditions. However, because of the irrational rotation in the second coordinate, there are no periodic orbits, and hence the mapping is not chaotic according to the definition above. Topologically mixing means that the system will evolve over time so that any given region or open set of its phase space will eventually overlap with any other given region. Here, "mixing" is really meant to correspond to the standard intuition: Attractors Edit Some dynamical systems are chaotic everywhere see e. Anosov diffeomorphisms but in many cases chaotic behaviour is found only in a subset of phase space. The cases of most interest arise when the chaotic behaviour takes place on an attractor , since then a large set of initial conditions will lead to orbits that converge to this chaotic region. An easy way to visualize a chaotic attractor is to start with a point in the basin of attraction of the attractor, and then simply plot its subsequent orbit. Because of the topological transitivity condition, this is likely to produce a picture of the entire final attractor. Phase diagram for a damped driven pendulum, with double period motion For instance, in a system describing a pendulum, the phase space might be two-dimensional, consisting of information about position and velocity. One might plot the position of a pendulum against its velocity. A pendulum at rest will be plotted as a point, and one in periodic motion will be plotted as a simple closed curve. When such a plot forms a closed curve, the curve is called an orbit. Our pendulum has an infinite number of such orbits, forming a pencil of nested ellipses about the origin. Strange attractors Edit While most of the motion types mentioned above give rise to very simple attractors, such as points and circle-like curves called limit cycles , chaotic motion gives rise to what are known as strange attractors , attractors that can have great detail and complexity. For instance, a simple three-dimensional model of the Lorenz weather system gives rise to the famous Lorenz attractor. The Lorenz attractor is perhaps one of the best-known chaotic system diagrams, probably because not only was it one of the first, but it is one of the most complex and as such gives rise to a very interesting pattern which looks like the wings of a butterfly. Other discrete dynamical systems have a repelling structure called a Julia set which forms at the boundary between basins of attraction of fixed points - Julia sets can be thought of as strange repellers. Both strange attractors and Julia sets typically have a fractal structure. However, no such restriction applies to discrete systems, which can exhibit strange attractors in two or even one dimensional systems. The initial conditions of three or more bodies interacting through gravitational attraction see the n-body problem can be arranged to produce chaotic motion. Minimum complexity of a chaotic system Edit Bifurcation diagram of a logistic map, displaying chaotic behaviour past a threshold Simple systems can also produce chaos without relying on differential equations. An example is the logistic map , which is a difference equation recurrence relation that describes population growth over time. Even the evolution of simple discrete systems, such as cellular automata , can heavily depend on initial conditions. Stephen Wolfram has investigated a cellular automaton with this property, termed by him rule Mathematicians have devised many additional ways to make quantitative statements about chaotic systems. Thus any real time series, even if mostly deterministic, will contain some randomness. A deterministic system will have an error that either remains small stable, regular solution or increases exponentially with time chaos. A stochastic system will have a randomly distributed error. To define the state of a system one typically relies on phase space embedding methods. If the error looks random, one increases the dimension. If you can increase the dimension to obtain a deterministic looking error, then you are done. Though it may sound simple it is not really.

Chapter 6 : Chaos In Ecology: Experimental Nonlinear Dynamics

The ECC has for nearly the last two decades been a forum to highlight the forefront of experimental work in the fields of chaos and nonlinear dynamics and to disseminate novel methodology to a broad range of fields of study.