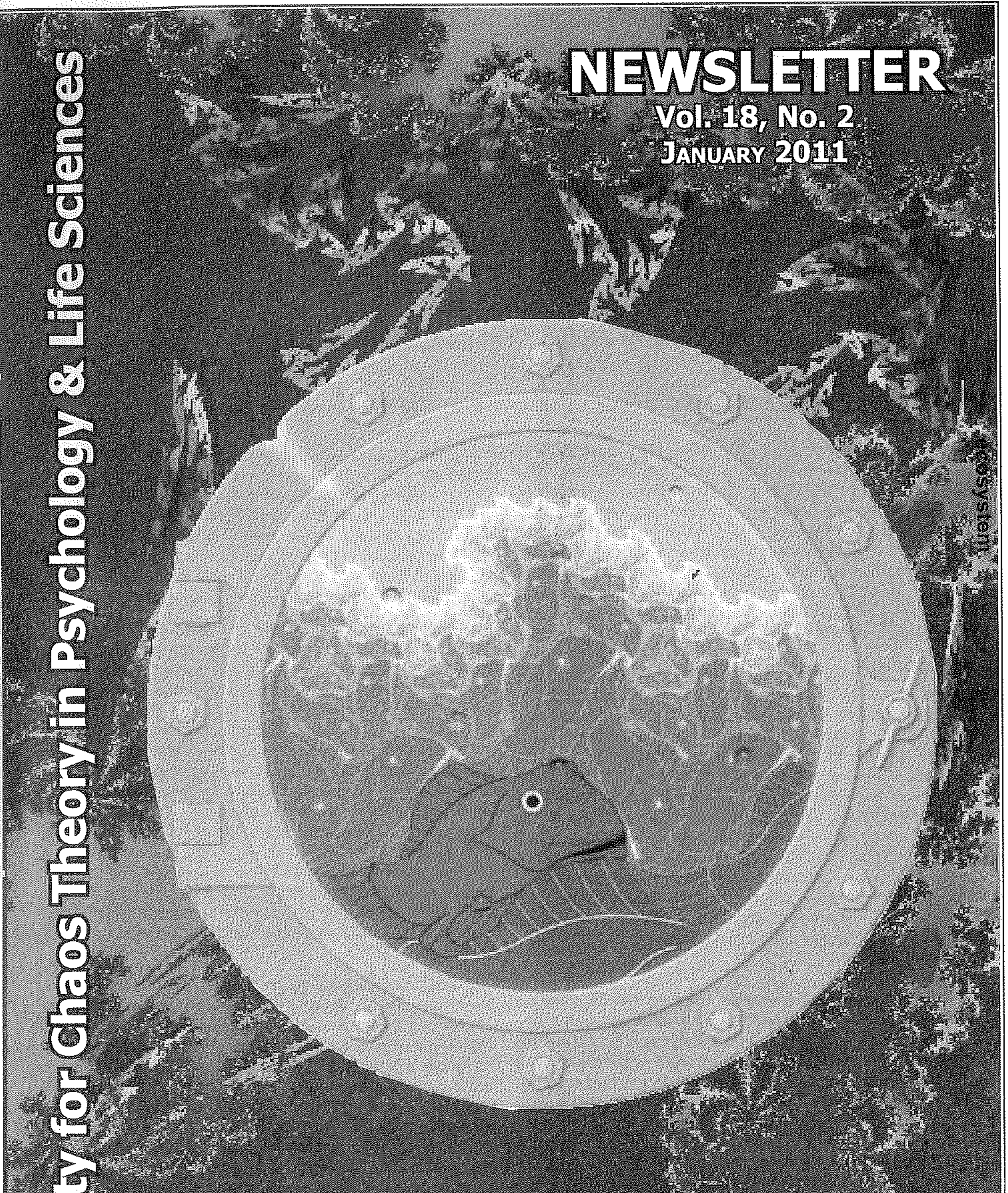
Society for Chaos Theory in Psychology & Life Sciences

NEWSLETTER

Vol. 18, No. 2
JANUARY 2011



Call for Papers

21st Annual International Conference

THE SOCIETY FOR CHAOS THEORY IN PSYCHOLOGY & LIFE SCIENCES

August 4-6, 2011
Chapman University, Orange California USA

Dave Pincus 2011
Conference Chair

AN INVITATION TO OUR CONFERENCE

This year, August 4-6 2011, will bring the 21st SCTPLS international conference to sunny Orange, California. The conference will include two prominent keynote speakers, four cutting-edge pre-conference workshops, 6-8 symposia, 30 plus concurrent sessions and 5-10 posters. We will also have an international group of 60-70 psychologists, physicists, mathematicians, researchers and others who all share a common focus in investigation and application using nonlinear dynamics. Now is the time to begin to prepare your abstract for submission.

As a former student member of SCTPLS starting in 1996, I have observed remarkable growth in the application of nonlinear dynamics across the branches of psychology, life sciences, organizational development, economics, and related disciplines. For those of you who have been around even longer (20 years or more) the growth of our work must seem even more astounding. Academic book publishers have been increasing their output of nonlinear titles in the behavioral, social and life sciences. High ranking journals across psychology and the life sciences have been more open to submissions involving nonlinear dynamical systems theory, methods, and applications. Meanwhile our own flagship journal, ***Nonlinear Dynamics, Psychology, and Life Sciences,*** is reaching its highest impact and immediacy ratings on record.

Now is an exciting and dynamic time to be involved in nonlinear science, and the annual international conference of SCTPLS provides an ideal opportunity to showcase ones achievements. Providing a small, focused conference with broad interdisciplinary and international scope, this summer is the time to share your interesting work among those who truly "get it."

Some critical conference dates: January 14 (Friday), call for proposals opens; March 8 (Tuesday), early-bird abstract submissions will receive a reply after this date; April 29 (Friday), call for proposals closes; May 17 (Tuesday), all acceptances finalized by Program Chair. Everyone is looking forward to seeing you at the conference this summer.

CALL FOR PAPERS and SYMPOSIA

We invite interested scholars to present and discuss recent developments in nonlinear dynamical system theory, which includes chaos theory, fractals, complex systems and related topics. Over the years, the annual conferences of the Society for Chaos Theory in Psychology & Life Sciences have inspired and supported scholars from an array of disciplines to look at new ways to develop their theoretical and empirical work in an integrated approach to life sciences.

The Society for Chaos Theory in Psychology and Life Sciences is a multidisciplinary organization. The topics covered by the conference include applications of nonlinear dynamics theory and techniques to problems encountered in any area of the behavioral, social and life sciences including psychology, sociology, economics, econophysics, management sciences, anthropology, aesthetics, education, biology, physiology, ecology, neuroscience and medicine. One or more of the following nonlinear concepts must be an explicit part of the presentation: attractors, bifurcations, chaos, fractals, solitons, catastrophes, self-organizing processes, cellular automata, agent-based models, network analysis, genetic algorithms and related evolutionary processes, dynamical diseases, or closely related constructs. The broad mixture of the disciplines represented here indicates that many bodies of knowledge share common principles.

The program will include workshops, invited addresses, symposia, panel discussions, a poster session, and sessions of individual papers. Advances in basic or applied research, developments in theory, reports of empirical results and methodological papers are all welcome. We continue to encourage all nonlinear scientists, including graduate students who might be finishing up a dynamical thesis or dissertation, to consider sharing their ideas through paper presentations, chairing a roundtable session, or by proposing other alternative presentation formats, such as posters, product demonstrations, short workshops, or debates around controversial topics.

INSTRUCTIONS FOR ABSTRACTS

Abstracts should be between 150-250 words for posters, individual papers, short workshops and other alternative formats. The connection to nonlinear dynamics, chaos, complexity, fractals or related concepts should be clear to the reader. Include organizational affiliation and contact information on each speaker or author.

Abstracts may be up to 500 words for symposia or panel discussion. For symposia, abstracts should reflect the content of EACH speaker's contribution. The format for a symposium is for all speakers to give presentations, followed by or interspersed with discussion. Symposia should present current research within a coherent theme defined by the title and abstract.

For experimental work, the background, aims and framework, methods and samples, results, conclusions and Implications should be clear to the reader. For theoretical work, the background, aims and framework, mode of inquiry, outcomes, conclusions and implications should be clear to the reader.

Abstracts for panel discussions should provide a brief overview of the topic, and indicate the relevant background of the panelist and sample questions they will address. The format for a panel discussion is an introduction to the topic and the speakers, after which the panelists address as series of questions or issues (rather than just giving a series of presentations).

Abstracts for workshops should present state-of-the-art information on techniques useful for conducting research or applications of nonlinear science in the behavioral, social and life sciences. They should be pedagogical in nature. Where applicable, the abstract should emphasize skills that attendees can expect to acquire.

For all abstracts: The connection to nonlinear dynamics, chaos, complexity, fractals or related concepts should be clear to the reader. Please stress what is the overall value added to the field (e.g. new method, new information, new perspective or issue, valuable confirmation of the present knowledge, adds clarity to present understanding). Also, please indicate on the submission form which of the following categories is representative of your submission:

Check all that apply: (1) Empirical (e.g., presentation of empirical results of a study), (2) Theoretical (e.g., empirically testable theoretical development), (3) Applied (e.g., organizational, business, product development or marketing, or involving clinical interventions), (4) Quantitative (e.g., computational or statistical modeling); (5) Qualitative (e.g., non-quantitative analysis of empirical data); 6) Philosophical or artistic (e.g., epistemology, philosophy of science, aesthetics, or audio-visual demonstrations)"

Each person submitting is limited to a maximum of two presentations as first author. It is acceptable to be a co-author on additional work submitted by others.

The deadline for submissions is **April 29, 2011**

Early birds will receive acceptances after March 8th

Abstract should be submitted electronically by visiting:

http://www.societyforchaostheory.org/conf/2011/cfp

Full Day Workshop on Nonlinear Methods

We have a new and different format for the pre-conference workshop this year. It is directed toward serious researchers, some of whom are beginners, and others who would just like to get a grip on methods topics once and for all. It is organized into modules, and a single registration fee (separate from conference registration) covers the whole program.

Intro to basic dynamics and workshop plan (SJ Guastello)

Phase space diagrams, correlation dimensions (Mark Shelhamer)

Recursion analysis (Deb Aks)

Power laws (TBA)

Nonlinear regression, including a little catastrophe theory (SJ Guastello)

Markov Chains (Steve Merrill)

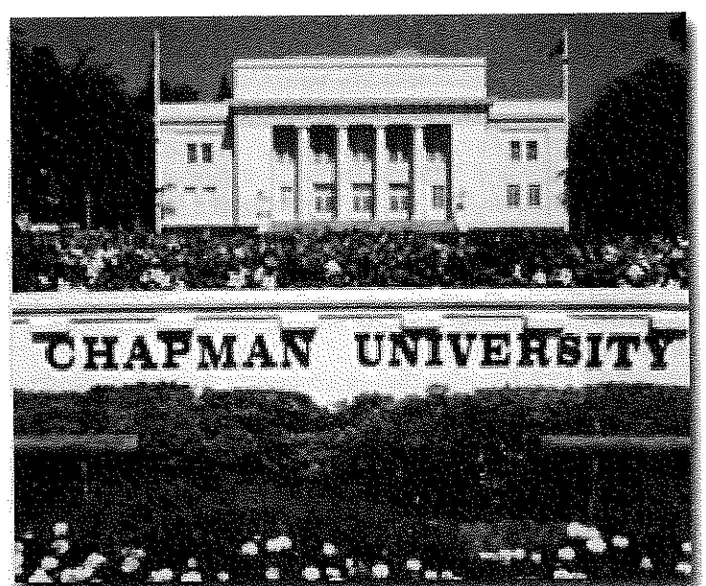
Symbolic dynamics / orbital decomposition (Dave Pincus)

Group discussion with the teaching panel.

Further details will appear in the next issue of the SCTPLS Newsletter. Watch your e-mail meanwhile!

Special Guests as Always

Polumnia Amazeen is our guest speaker for the Sunset Session. See page 13.



ABOUT THE LOGO

The logo for this year's conference, "Grouped Groupers" is "© 2001 Robert Fathauer and used with his permission. You can see more of Robert's fascinating artwork on http://members.cox.net/fathauerart/index.html

Feature Article

Nonlinear Dynamics in Stock Prices: Traders' creativity in complex information environments

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The Efficient Market Hypothesis (EMH) rules out the existence of any discernable patterning in stock prices that might be used to achieve abnormal profits. Traders called chartists, who are looking for such patterns, are often blamed for noise in the market as their buying and selling behaviors create anomalies that are short lived and randomly distributed. Under EMH, information is available to all investors and is accurately incorporated in stock prices. But when information complexity increases and its analysis becomes costly, markets cannot find equilibrium as traders resort increasingly to rule based trading, herding and imitation. Rule based trading evolves on the basis of historical prices, high frequency quotes and limit order book data resulting in algorithmic trades that do not involve the fundamental valuations of com-panies. Recognition of the interplay of these dynamics lends itself to detecting periods of market "bubble build up" and the development of resilience measures aimed at preventing market crashes. The goals of the paper are to explain the aggregate market behavior resulting from increased traders' interdependence and to propose a set of nonlinear topological and dynamic measures of market inefficiency.

INTRODUCTION

Asset pricing and risk modeling are areas flooded with sophisticated and technically correct models. The problem is not in the lack of asset pricing models and risk management techniques available but in understanding the complexity and interconnectivity of a financial system that tends to scale free self-organization and synchronizes towards a chaotic attractor. Better understanding of the scale free regime and early detection of asset bubbles will bring about better suited valuation and asset pricing techniques along with macroeconomic intervention strategies to prevent crashes.

Scale free theories of bubble build up regimes that tend towards a critical point of crash are discussed in the Fractal Finance models of Yalamova and McKelvey (2009, 2010). A model of the shift in market dynamics from an Efficient Market with a randomly arriving transparent information and heterogeneous independent traders regime to a bubble build up situation in a complex and ambiguous information environment with difficult to valuate financial innovations is described in Yalamova and McKelvey (2009). The latter regime leads to imitation and clustering between traders evolving toward a dominant trading rule as described in Lebaron (2001). The scale free network in this case synchronizes differently and the attractor is the critical point. Support for this theoretical model may also be found in Fama (1965) with the suggestion that dependence in the noise generating process will produce "bubbles" in the price series but if there are large numbers of sophisticated traders, they will cause the bubbles to burst. Similarly Sethi's (1996) model shows local instability is possible if the adjustment of prices is rapid, chartist demand is highly sensitive to changes in expectations, and the share of wealth in chartist hands is sufficiently large. In contrast, a unique equilibrium is formed when prices are equal to fundamental values and stability of price dynamics ensues when the chartist share of market wealth is sufficiently small.

In order to go beyond classic financial asset pricing theory, we attempt to further legitimate the separate-but-equal statuses of EMH and Fractal Finance by encouraging research on nonlinear dynamic models. In this regard, we especially focus on dynamics causing traders to shift from one regime to the other. Research on extreme events (e.g. crashes) and their underlying scale-free dynamics is of particular interest for the overall understanding of market functioning as complex systems reveal their characteristics under stress better than in normal conditions.

This paper is based on the phase transition model of Yalamova and McKelvey (2010) that describes how market switches from random heterogeneous independent traders' regimes (EMH) to non-linear dynamics, loss of traders' heterogeneity, clustering stemming from herding and imitation lead to a regime characterized by scale free networks and bubble build up. Detecting the existence of the latter regime requires a new approach to asset pricing and, as the expected returns become stochastic, a reassessment of future returns is necessary. In such cases, we agree with the Lin et al. (2009) model of price path during bubbles exhibiting a deterministic log-periodic power law (LPPL) component and estimation errors following Ornestein-Uhlenbeck (O-U) process. The Lin et al. model also describes the dynamics of co-existence between rational and noise traders. Their results show promise in detecting bubbles, identifying a consistent universal super exponential acceleration of price decorated with log-periodic oscillations with mean reverting residuals.

A different method for detecting clustering among traders and the synchronization dynamics of the scale-free network towards a new attractor is proposed in Yalamova (2009). Here the suggestion is to use the Spectral Clustering and Partition Decoupling Method for the specification of the stochastic discount factor in the volatility-confined model with a LPPL drift (Lin et al. 2009). This dynamic updating of the model based on empirical results will capture the emergent collective organization of the complex financial system.

The paper is organized as follows: section two reviews the changes in efficient markets when information becomes costly (i.e. when information is difficult to analyze since it is complex or ambiguous), section three discusses power laws as a signature of complexity and the related detection methodology, section four reviews network partition and synchroni-zation methodology for the specification of the stochastic discount factor, and section five concludes with the advantages of dynamically adjusted asset pricing models in a regime of emergent market self-organization.

TRANSPERANT, FREELY AVAILABLE INFORMATION VS COMPLEX INFORMATION

The Efficient Market Hypothesis suggests that, at equilibrium, arbitrage profits are eliminated if information is available to all participants. Grossman and Stiglitz (1980) argue that if information gathering is costly, a competitive Walrasian market, (i.e. price equals supply and demand) is not always in equilibrium. Moreover, they showed that when the efficient market hypothesis is true and information is costly, competitive markets break down. Informed traders realize that they should stop paying for information if they can do no better, net of the cost of information, than uninformed traders. Therefore, having some stable fraction of informed traders under such conditions does not obtain. Yet having no one informed is not an equilibrium condition either as each naïve trader believes that there are profits to be made from becoming informed.

In an efficient market with transparent and inexpensive information, equilibrium is attained and trading is thin. Trades take place because traders differ in investment horizons, beliefs, and endowments. In similar fashion to Grossman and Stiglitz (1980), we do not reject EMH but attempt to extend it to conditions when information is complex, i.e. costly in terms of analysis (Yalamova & McKelvey 2010). Our models rely on Grossman and Stiglitz (1980) findings that when informed traders get very precise, inexpensive information, equilibrium exists and the market price reveals most of the informed traders' information. When information is costly prices cannot perfectly reflect information; therefore there should be room for compensation of informed traders and incentives to acquire information.

In a double auction market, prices experience upward or downward pressures as a result of the balance between buy and sell orders. Markets at equilibrium should eliminate arbitrage; fast incorporation of information in the security prices should keep prices close to fundamental values. Symmetric distribution of buy/sell orders prevails in efficient market at equilibrium. Temporary anomalies are allowed, their randomness and symmetric occurrence precluding arbitrage. Information is transparent and freely available, noise in the market is offset by rational decision making, and anomalies are short lived.

If information complexity and ambiguity increases, however, analysis is costly and imitation in trading (herding) is optimal. As the level of noise increases, information ambiguity prevails and the market is pervaded by uncertainty, then efficient information processing and probabilistic decision making become more difficult.

The high variability of stock market returns is a signature of collective phenomena such as imitation or 'herd' behavior. Herding in financial markets is well documented empirically. A quantitative link between bursts of volatility and herd behavior can be established through examination of order flows that display the aggregation of individual demands independent of the mechanism of herding whether it is a sequential information cascade or random formation of groups through clustered networks.

In an environment of increased uncertainty, rational probabilistic decision making is impeded and the bimodal demand function (Plerou et al., 2003) signals herding behavior. At a certain level of information complexity, traders resort to the alternative: rule based trading. Information cascades, herding, and rule based trading create a complex network (self-organization) among traders and leads to a power-law in the autocorrelation function of returns, indicating long memory and positive feedback.

The reversal frequency of the market sentiment is related to the increasing hazard rate of crash producing log periodicity in the price oscillations. In the bubble build up, rational traders evaluate the increased hazard rate and adapt their speculative strategy. Sornette (2003a) describes the build-up of cooperative_specula-tion, which often translates into an accelerating rise of the market.

Even when some traders act sequentially rather than concurrently, the herd-like behavior of others can impede the flow of information and a slight prevalence of public information (e.g. observing others' actions) is then sufficient to induce traders to ignore their private information and follow in the direction of the crowd (information cascade). That such information cascades might result from the observation of the order flows independent of traders' private information, can mean that each and every participant may have taken the wrong action. This state is thus characterized by fragility in that a little bit of public information (or an unusual signal) in the opposite direction can overturn the cascade.

De Long et al. (1990), argue that if rational speculators purchase ahead of noise demand, this may trigger positive-feedback trading. An increase in the number of forward-looking speculators can increase volatility about fundamentals. Fundamentalists base their decision on the deviation of the asset prices from fundamentals and chartists on the trends they discern from past observations of the data. Their interaction is described by the disequilibrium models of Beja and Goldman (1980) and Chiarella (1992). The first model is linear and instability is global. The second model is a nonlinear version and prices oscillate around but never converge to fundamentals. The model agrees with the assertion of DeLong et al. (1990) that unboundedly rational traders take full account of the presence of noise traders, and destabilize prices to exploit the adaptive behavior of the latter.

Imitative behavior among traders leads to loss of heterogeneity and LeBaron (2001a, b) shows that as investment rules coevolve toward a single super-rule, the market collapses.

We do not offer an alternative to EMH/CAPM but extend the existing framework to accommodate situations with higher information complexity, interactions with positive feedback (Minsky, 1982, 1986), and extreme events that cannot be simply explained by presuming independent-additive data points and normal distributions. For example, the development of the "herding behavior" literature in finance (Banerjee, 1992; Bikhchandani, et al. 1992; Prechter, 1999; Brunnermeier, 2001; Rook, 2006;) marks a significant recognition that interdependent trader behavior may result in skewed distributions of stock market prices and, therefore, offers the first underlying explanation of behaviors that may begin as Holland's (2002) "tiny initiating events," but later scale up into extremes.

At a certain level of information complexity, or when the buy/sell rule of another trader or group of traders is leading to obvious financial gain, a trader usually resorts to the alternative of rule-based trading instead of behaviour consistent with EMH. Rule-based trading, herding, and information cascades create complex networking (self-organization) among traders, which then leads to a power-law in the ACF of absolute log returns (volatility) that can be detected in the market data with scale-invariant methodology such as that employing wavelet analysis. Details on estimating Hurst exponents and autocorrelation functions with wavelets can be found in Yalamova (2003, 2005).

COMPLEXITY MEASURES

Theories of asset pricing dynamics that challenge the EMH view fluctuations as arising from underlying systematic causes that lead to increased correlations in extreme events. Plerou et al (1999) analyze the cross-correlation of stock price changes in an attempt to separate noise and interaction between two companies effect on correlation, and admits the difficulty of measuring the interaction strength between two companies. We argue that stock price correlations actually reflect coordination of traders' activity that might be initiated by different factors related to news or noise. After all, what determines price changes are trading orders. Therefore, we propose that price changes actually measure the interaction strength among traders (self-organization), especially in a complex information environment when rational decision making is impeded and imitation creates positive feedback in trading behavior.

Synchronization phenomena of interacting traders are hypothesized as the cause of log-periodic oscillations of prices before significant drawdowns (Yalamova 2010). Inefficiency in the stock market persists as a result of coordination among traders and growing clusters of correlated trading behavior changes the structure of the sectorial market decomposition. Quantifying the level of inefficiency will allow policy makers and regulators to introduce appropriate measures to prevent crashes and reduce effects of recessionary events. These complexity parameters for time series should detect self-organization in the system:

Fractal Dimensions

Yalamova and McKelvey (2010) introduced the Hurst exponent and the power laws in the autocorrelation function to detect the emerging fractal state in our market model. If time series exhibit long memory, they display significant correlations between observations separated in time – i.e., the correlation does not go to zero for a long lag. Therefore we focus our discussion around the evidence of increased price-volatility persistence in periods before crashes. The ACF of log returns is effectively zero for lag > 2, while the ACF of log-return absolute values (as a straightforward measure of volatility) decreases very slowly and remains positive, even after a lag of 500, before decaying to zero. Such results suggest that the returns of the stock market are uncorrelated while their volatility has long-range dependence. A logarithmic-scale plot of the autocorrela-tion function gives the same visual illustration of power laws as described in the explanation of PL distributions above. Long-memory is defined mathematically in terms of autocorrelation. The time series of the absolute value of returns exhibits autocorrelation, when return $|r_i|$ is correlated with $|r_{i-s}|$ and s is a measure of time increment. The autocorrelation function ρ takes a power-law form with constant C and exponent α:

$$\rho(s)=Cs^{-\alpha}$$

The fractional integration parameter α of the ACF is related to the volatility scaling (Hurst) exponent as:

$$H = 1-\alpha/2$$

Volatility is random if the Hurst exponent is equal to ½, which indicates totally random, so-called 'Brownian motion,' movements. Volatility persistence as measured by the Hurst exponent increases above ½ during periods of increased information complexity. More specifically, if H > ½, rule-based trading, herding, imitation, and increased mutual influence among traders leads to log-periodic oscillations of prices appearing as precursory bubble build-up patterns before crashes.

The self-organization process causing the foregoing market dynamics shows up in the form of power-law distributions of returns as well as in a power-law of the volatility. Yalamova (2003) shows the increasing persistence in volatility as measured by the Hurst exponent in a number of stock market indices in periods of 2–4 years before significant drawdowns (crashes) such as those that occurred in October 1987 and March 2000.

A 'fractal dimension' allows us to measure the degree of complexity by evaluating how fast our measurements increase or decrease as our scale becomes larger or smaller. The methods for measuring fractal dimension rely heavily on the power law, which allows extrapolation and prediction over a wide range of scales.

Power laws describe empirical scaling relationships that are emergent quantitative patterns of structure (A) or dynamics (B) that are self-similar or fractal-like over many orders of magnitude. The Hurst exponent is related to the fractal dimension, which gives a measure of the roughness of a surface. The relationship between the fractal dimension, D, and the Hurst exponent, H, is:

$$D = 2 - H$$

The Hurst exponent provides a measure of whether the data are a pure random walk or have underlying trends.

Plerou et al. (1999, 2002) among others suggest that there exist three kinds of fluctuations in stock price returns: market wide, synchronized groups and random. However, the Hurst exponent alone cannot be used as a measure of market (in)efficiency. We pursue other indicators below.

Permutation Entropy

Entropy captures uncertainty and disorder in a time series without imposing constraints on the theoretical probability distribution. A pure random walk with an uncorrelated string of variables exhibits maximum entropy, while the negative entropy relative to the maximal can be regarded as a measure of predictability and inefficiency.

In the process of evaluating entropy one has to determine the probability distribution associated with the data. We argue that in Finance one should be more accurate in depicting the temporal structure when evaluating the probability distribution. Bandt and Pompe (2002) propose a method revealing important details about the ordinal structure of time series. Then the estimated permutation entropy measures the variety of possible ordering based on a comparison of n neighboring values in the time series and should increase with n. This complexity measure behaves as a Lyapunov exponent, while it is easily calculated even in the presence of dynamical or observational noise.

Lyapunov exponent

Chaotic sequences are generated deterministically from a dynamical system. If two orbits are created with identical initial data, x_0, then the orbits are the same. What makes the dynamical system "chaotic" is the fact that orbits arising from initial data which are arbitrarily close grow apart exponentially. Random (sometimes called stochastic) processes are fundamentally different. Two successive realizations of a random process will give different sequences, even if the initial state is the same. Since a random process is non-deterministic, numerical computation of a Lyapunov exponent is not well defined.

One fundamental assumption needed to apply the proposed method for the calculation of the Lyapunov exponent is that the data were generated by a deterministic process, i.e. they were not the result of a purely stochastic process. This concern can be addressed with the computation of the Hurst exponent.

Abarbanel (1996) measures the average rate of growth or decay along each of the principal axes in the d-dimensional state space, defining λ_i for each dimension d. The problem in time series analysis is that the physical state space is unknown, and the spectrum is computed in some embedding space. Thus the number of exponents depends on the reconstruction, and might be larger than in the physical state space. However, such spurious exponents can be avoided as shown in Stoop and Parisi (1991).

The largest Lyapunov exponent (λ) specifies the maximum average rate of divergence, or instability. The presence of a positive exponent is sufficient for diagnosing chaos and represents local instability in a particular direction. For the existence of an attractor, the overall dynamics must be dissipative, i.e. the sum across the entire Lyapunov spectrum is negative.

Rosenstein et al. (1993) suggest that the existing methods for λ estimation suffer from at least one of the following: (a) unreliable for small data sets, (b) computationally intensive, and (c) relatively difficult to implement As a result, they propose an algorithm to compute λ by estimating the separation between pairs of neighboring points in state space. (Reconstruction of the state space using the method of delays is described above). By plotting the log of the divergence versus time, λ is estimated by a least squares fit to the linear region. (The algorithm is developed in Matlab.)

This method is appropriate for the initial stage of the project being proposed here, when the goal is to confirm the presence of chaotic dynamics with the largest Lyapunov exponent. The identification of multifractal spectra for Lyapunov exponents as described by Barreira (1997) is a natural extension of the empirical tests.

Negative largest Lyapunov exponent as evidence of stochasticity should direct the research into multifractal predictability, where the advantages of stochastic rather than deterministic sub-grid parameterization may be exploited for stochastic forecasting as evidenced by Schertzer and Lovejoy (2004).

SPECTRAL CLUSTERING AND NETWORK SYNCHRONIZATION

Synchronization phenomena of interacting traders are hypothesized as the cause of log-periodic oscillations of prices before significant drawdowns. The dynamical process towards synchronization may exhibit different patterns related to the topology of the complex network of agents. It has been shown that highly interconnected agents synchronize more easily than those with sparse connections (Vega et al. 2004, Oh et al. 2005). Furthermore, those highly connected agents form local clusters involved in a network with larger groups up to the final state where the whole population is involved.

Arenas et al. (2006) propose spectral theory of the Laplacian matrix of a graph for the analysis of any complex networks. Different time scales of the correlation structure reveal the dynamics towards an attractor.

We propose that each group of agents trading the same stock forms a node of the network, i.e. each node is modeled as a phase oscillator. The synchronization model of coupled phase oscillators studied by Kuramoto (2003) assumed mean-filed interaction. Therefore, if the oscillators are identical, there is only one attractor of the dynamics.

In efficient markets with (identically) rational agents, randomly arriving news is incorporated in asset prices quickly. The attractor is market equilibrium, the price is "right". Random networks though, synchronize differently than the scale free networks that we argue develop in a bubble build up regime. We attempt to describe the changes of the topological structure of trader's network with spectral clustering and partition decoupling methods recently applied to equity markets. The goal is to confirm the increasing coupling and loss of heterogeneity leading to a new attractor: the "the critical point" and crash.

Revealing the dynamics of the traders' complex network in periods before and during extreme events should play an important role in the development of models of stock market dynamics and empirically testing for the emergence of collective signals out of the noise in complex systems.

Understanding the mechanisms of self-organization of market participants leading to bubble build up and ending either in a soft-landing or a crash will allow regulators to develop better intervention strategies and guiding policies to prevent negative outcomes.

As noted earlier, Plerou et al. (1999, 2002) among others suggest that there exist three kinds of fluctuations in stock price returns: market wide, synchronized groups and random. Identification of stock groups based on the correlation matrix eigenvalues was the subject of previous research in an attempt to reveal changes in correlation and better portfolio strategy.

Network topology plays an important role in dynamic behavior. Graph theoretic analysis on trader's networks applies some of the above mentioned methods in Yalamova (2009) while here we focus on collective synchronization phenomena that appear in stock prices before crashes. We propose a model of synchronization of traders' behavior leading to log-periodic patterns of index prices as documented by Sornette and colleagues (1998, 2001).

Multiresolution can be achieved with the application of wavelet transform at different scales. The graph Laplacian of the correlation matrix of returns should be obtained following SI Leibon et al. (2008). Recent studies show the spectral information of the Laplacian and the synchronization dynamics relationship. The master stability equation of Pecora and Carroll (1998) and eigenvalue ratios are used to determine the stability of synchronization and the heterogeneity of the topology. Arenas et al (2006) analyze the whole eigenvalue spec-trum of the Laplacian matrix revealing many aspects of the topological structure, e.g. the number of discon-nected components, the relative difference of time scales, and the existence of hubs. Moreover, the eigen-value of the Laplacian reveal the dynamics towards synchronization through the linearized dynamics of the Kuramoto model:

$$\frac{d\theta_i}{dt} = -k\sum_j L_{ij}\theta_j, \qquad i = 1......N$$

where θ_i is the phase of i and the solution in terms of the normal modes $\varphi_i(t)$ with eigenvector matrix B is:

$$\varphi_i(t) = \sum_j B_{ij}\theta_j = \varphi_i(0)\exp(-\lambda_i t)$$

This method also allows detection when the oscillators break through the synchronization threshold forming clusters, the R1 information complexity level in the Yalamova-McKelvey (2009) model.

A link between dynamics and topology can be detected analyzing the whole spectrum of the Laplacian matrix of the network graph. Following the methodology described in Arenas et al. (2006), we rank the eigenvalues of the Laplacian in ascending order. This reveals the topological structure of disconnected components, relative differences of time scales, and the existence of hubs in the network as explained in the above reference.

CONCLUSIONS

The paper summarizes a variety of methods to detect self-organization in the stock market that leads to bubble build up and crash. Empirical results will allow us to confirm the existence of patterns in market self-organization before crashes. Better understanding of the dynamics will allow planning regulation and intervention strategy to mitigate the consequent action as the causes of crash versus soft-landing are not fully understood although the differences in the patterns of price diffusion have been documented.

This approach also delivers new theoretical insights and quantitative tools to behavioral finance researchers. The model described in Yalamova and McKelvey (2009) attempts to reconcile the differences between efficient market thinking and behavioral finance by creating a unified framework which accommodates both fields in different regimes. These differences in the dynamics require different research methods. To the best of our knowledge, topological descriptions of far from equil-ibrium trader networks have not been attempted in behavioral finance. This method will enable quantitative analysis of connectivity and herding patterns among traders. Moreover, synchronization dynamics research in finance promises better understanding of cash flow and liquidity changes to avoid crisis.

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Advances in Brain Connectivity

Reported by Stephen J. Guastello, *Marquette University*

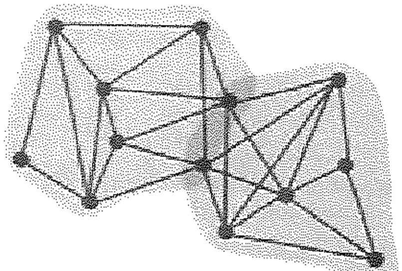

Fig. 1. Yan et al.: Networks are connected.

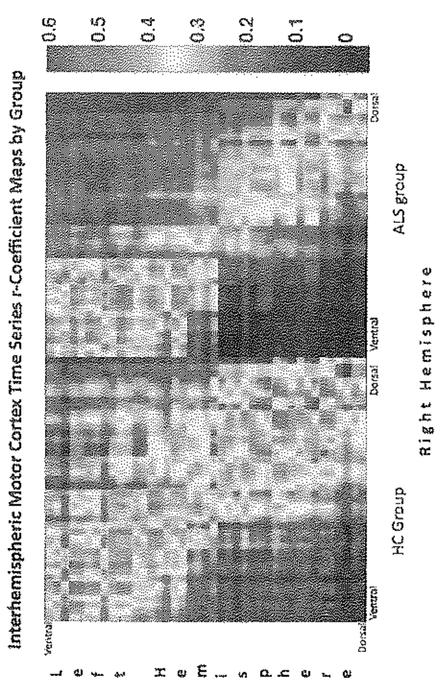

Fig. 2. Sample correlation diagram from Welsh et al.

The Second Biennial Conference on Resting-State Functional Brain Connectivity met at the Medical College of Wisconsin September 16-19, 2010. The conference drew approximately 300 neuroscientists, physicians, psychologists, computer programmers, and biomedical engineers from North America, Europe and the Pacific Rim. Presentations in 20-minute blocks spanned three days plus poster sessions. Nonlinear dynamics were salient in about a dozen of the contributions, a few of which are highlighted here. The conference was chaired by Christopher Pawela from MCW. MCW is well-known as a center of neuroscience research using functional Magnetic Resonance Imaging (fMRI).

BACKGROUND

A brain in resting-state – not performing any deliberate task – is very active. About 15-20 percent of the neurological activity is associated with involuntary actions such as breathing, heart rate, and keeping the system alive and ready to respond to actual task demands. More than a third of activity, however, is attributed to "noise," some of which is machine-related and some is the "noise in the brain" that we have heard so much about lately. The discovery was initially reported by Biswal et al. (1995) at MCW and has since generated thousands of citations in subsequent research.

The fMRI itself registers images from metabolic activities of brain cells that transpire when neurons fire. The images are 3-D arrays of activity levels that are organized in 29 vertical slices, each of which is subdivided into a 64 x 64 array. Each of these 118,700+ *voxels* is thought to contain approximately 10,000 neurons. It takes about 2 seconds to scan an entire human brain. The images that appear in the literature could be one of the slices from one brain, or 2-D or 3-D composites based on a sample of human participants with the same condition or doing the same tasks. The system's software, which is quite elaborate overall, has an anchoring algorithm that aligns the voxels from brains that are inevitably of different sizes, and controls for the human operator to determine how much residual activation should be interpreted as "important" for making a particular image.

An important product of fMRI research is the resolution of the controversy between localization of function and Lashley's findings that memory was distributed throughout the brain and not readily localized at all (Gonsalves & Cohen, 2010). Nonlinear dynamics researchers, notably Freeman (2000), contributed substantially to the identification of meso-level circuits that connect brain areas when a mental task is performed. The circuits dedicated to a task change during the learning process and even over the life span.

fMRI and other brain imaging techniques have some advantages over EEGs because EEGs are read from the scalp and it is not easy to trace the activities of the deeper regions of the brain that lead to the scalp readings. Neuroscientists, nonetheless, have remaked that the information content from brain images is still crude at best and modern phrenology at worst, given the relatively crude spatial and temporal resolution of the imaging technology (Vul, Harris, Winkelman, & Pashler, 2009). Thus a special section of *Perspectives in Psychological Science* (Diener, 2010) was dedicated to redirecting psychological research with these media. As one can imagine, better psychological and neurological theories are needed, which is where nonlinear dynamics can make some important contributions.

NDS IN BRAIN IMAGES

Networks are prominent in recent fMRI research. The first challenge is to determine where a network begins and ends (Fig. 1, from Yan, Kelley, Goldberg,

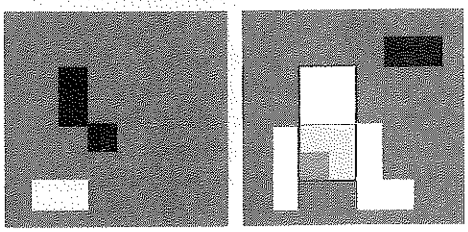

Fig. 3. Two images from a rat's brain.

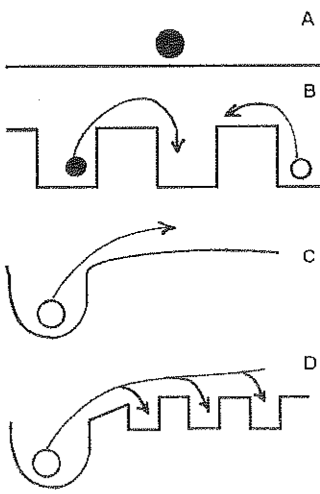

Fig 4. Deco: Comparison between supposed and actual resting state dynamics.

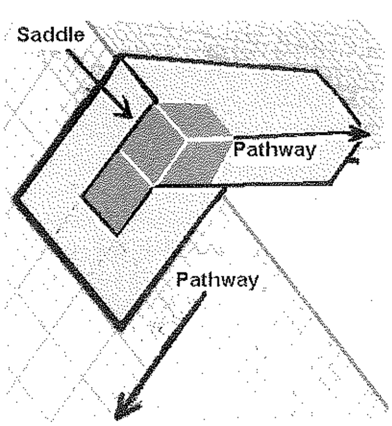

Fig. 5. High activation region resulting from the intersection between two pathways.

& Biswal, 2010). Here topological network theory, such as the type found in slower-moving social networks has been promising (Sporns, 2010). Using it, however, requires the reduction of voxel areas to a much smaller number. Figure 2 is a correlation diagram (Welsh, Jelsone-Swain, Seidler, Hovatter, Gruis, 2010), generic to many fMRI studies, that depicts correlation levels among voxel regions – so many in fact that the data are expressed in closely-packed colored cells rather than two-digit numbers. Some of the correlation diagrams shown during the conference presentations bore strong visual resemblance to recursion plots. Although the connection has not yet been investigated directly, Biancardi et al. (2007) did suggest the possibility of applying recursion plots to brain image data.

Independent components theory (McKeown et al., 1998) is an application of factor analysis for narrowing the voxel regions into small numbers of active groups. An important challenge, however, is that brain activity involves both activation and inhibition processes; negative correlations are not only possible, but can flip to positive and back again during a neurological process (Bandettini, 2010). Correlations also involve different times. The distribution of distances between activation areas is expected to be related to the lag between activations between nodes that are otherwise correlated (Deco, 2010).

Figure 3 is a stylized rendition of two images of a rat brain fMRI from Bhagat Biswal's (2010) after-dinner presentation. The differently colored sections actually flash on and off. According to Biswal, we need a metric that can compare and characterize the two flashing images. Here I would suggest (again) that entropy metrics and symbolic dynamics could provide the basis of a solution (Guastello, Nielson, & Ross, 2002). Brute-force analysis of activation sites at the voxel level is computationally overwhelming, however, and cogent aggregation procedures are needed (Guastello, 2011).

The attractor construct is also promising, and Deco's (2010) presentation reminded us about multistability in brain dynamics. Node dynamics consist of excitatory and inhibitory neurons. The complexity of interactions between nodes varies. Some nodes synchronize for a while, then, because of the influence of noise, de-synchronize. Based in part on the principle of stochastic resonance, we observe noise-driven transitions between multistable states. The resting state potential may *seem* like Fig. 4a, but it is more like Fig. 4b, where the control point jumps in and out of attractor states that are relatively shallow. Similarly, when a task is presented, the control point goes into an attractor well, but does more than just leave the well when the task ends as depicted in Fig. 4c. It can exit to any of several possible attractor states associated with resting state, as depicted in Fig. 4d.

FRIED EGG ATTRACTOR

Some goals of brain image analysis involve finding one or more attractors. For instance, if one were to develop a neural implant it would need to be lodged in the correct location specific to the individual (Nathan, 2010). If one were to examine a voxel slice in 2-D it is often possible to find a very high activation area in the middle of an irregular region where the activation level was high but not nearly so high. The image would resemble an egg yolk in the middle of an egg white. Dominic Nathan and I found a few configurations, however, where the apparent epicenter of the attractor was not located in an "ordinary" center of an activation region; the location of the highest activation was very lop-sided. Thus Fig. 5 conveys how an apparent attractor could be a saddle point that results from the convergence of two or more pathways. The converging pathways are often not discernible until one considers 3-D image sections.

Needless to say we decided not to implant any gadgets into anyone's brain for a while. I would not hesitate, however, to implant the idea that nonlinear dynamics is loaded with potential for bridging the gap that currently exists between what neural images can show, what we really need to know to use them, and how we need to make the imaging techniques work better to convey neuroscience realities.

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Right: "Bidirectional implant" by Rob Harle.

Call for Papers

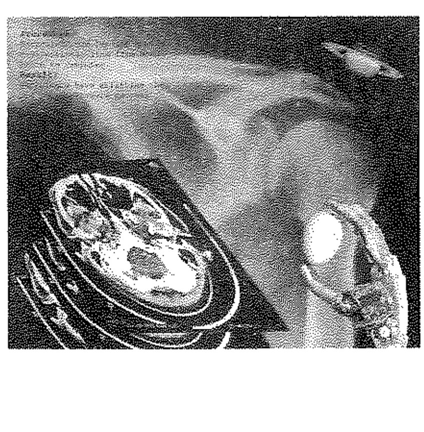
Nonlinear Dynamics, Psychology, and Life Sciences
Special Issue on
Dynamics of Brain Functioning

Advances in brain imaging techniques have allowed researchers and practitioners to visualize networks of brain cells that activate under various conditions. We are asking questions such as: How are nonlinear dynamics inherent in brain imaging data? How can the nonlinear properties inherent in brain imaging data inform us regarding brain functionality? What new adaptations to nonlinear analysis can be made to provide better answers to the foregoing questions?

Potential papers could include such topics as: Resting states and task activation patterns, determination of network properties, locating or identifying attractors and bifurcations, multistability patterns, entropy functions, healthy and pathological comparisons, EEG, fMRI, PET, and related data sources and comparisons, and drug-related effects.

Contributions may be theoretical or empirical. Theoretical papers should be firmly grounded in the extant literature and culminate in new and testable principles involving nonlinear dynamics. Manuscripts that are heavy on conjecture with little reference to evidence are not encouraged. Reviews of the relevant literature on applications of nonlinear dynamics are also welcome, if they synthesize and interpret this material in novel ways. Empirical papers may include simulations or analyses of real-world data. Articles will be reviewed by two or more experts in the relevant field.

The purview of the journal is critical to the inclusion of articles: *Nonlinear Dynamics, Psychology, and Life Sciences* publishes papers that augment the fundamental ways we understand, describe, model, and predict nonlinear phenomena in psychology and the life and social sciences. One or more of the following nonlinear concepts must be an explicit part of the exposition: attractors, bifurcations, chaos, fractals, solitons, catastrophes, self-organizing processes, cellular automata and agent-based models, genetic algorithms and related evolutionary processes, neural networks and network behavior. The broad mixture of the disciplines represented here indicates that many bodies of knowledge share common principles. By juxtaposing developments in different fields within the life and social sciences, the scientific communities may obtain fresh perspectives on those common principles and their implications. Because the journal is multidisciplinary in scope, each article should make an original contribution to at least one substantive area and, to the extent possible, illuminate issues beyond that area's boundaries.



Additional information for the preparation of articles for submission can be found on the journal's web site. Abstracts are requested prior to submission in order to assist with the organization of the issue contents, and they are welcome any time before the paper submissions deadline. Send abstracts by e-mail to the editor in chief, stephen.guastello@marquette.edu by January 31, 2011. Full-text papers need to arrive by April 30, 2011. Reviews completed by June 30, or sooner to the extent possible. Revisions and final edits should be received by September 1, 2011. Publication in January or April, 2012.

We look forward to receiving your abstracts and papers. If you have any questions about the project, please do not hesitate to contact us.

Sincerely,

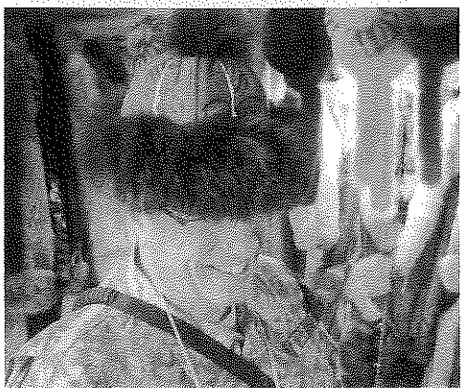
Stephen J. Guastello, Ph.D., Marquette University, Milwaukee, WI

Sifis Michaeloyannis, M.D. Medical School, University of Crete, Greece

Robert A. M. Gregson, Ph.D., DSc., Division of Psychology, Australian National University, Canberra.

Special Issue Co-Editors

News from Members



Dietz's new hat

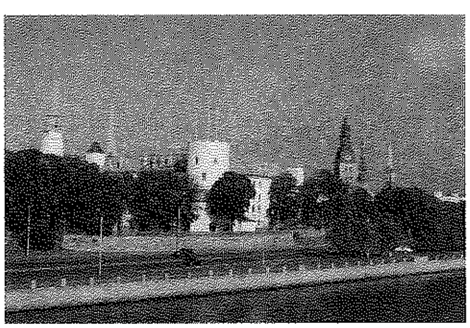
RED TEAM IN AFGHANISTAN **From Steven Dietz...**

Having a wonderful time here in Afghanistan. Well, maybe not wonderful, but I have lost close to 25 lbs. I've been applying complexity theories to almost every project I'm involved with. My days are 12-17 hours broken up with meals, working out, a few minutes each day to send some e-mails, and the occasional power nap. There are a lot of PoliSci guys here and a few History and Anthropology PhDs. Also, some Psychology guys. As you know, when you have a PhD you get to learn the PhD secret handshake. This means that I get pulled into a lot of meetings because we most be 'smart,' and then get asked to respond to a variety of topics we really don't know anything about. Typically, we (the PhDs) will look at each other and then one of us will begin talking very theoretically (topic is less important than the size of the words used). Afterwards the team leaders always say that they had input from a PhD and that the plan is on the right track. Oh well, there are many ways to row a boat. I was in the news as well with an AP article, which I think you will find amusing, here's the link:
http://news.yahoo.com/s/ap/20100925/ap_on_re_as/as_afghanistan_red_team
Thanks for keeping me on the distro -- looking forward to seeing everyone in CA next year.

CROSSING BOUNDARIES **From Glenda Eoyang...**

2010 was a year for crossing boundaries at Human Systems Dynamics Institute. We formed partnerships with ALIA Institute, Edna Pasher and Associates, and the Ball Foundation; delivered HSDP Certifications - ten-day professional certificate courses - outside of the Twin Cities in Washington DC, London, and Ottawa, as well holding our annual HSDP in the Twin Cities; founded Centers (and Centres) for HSD in Israel and the United Kingdom; spoke publicly about racism and social justice; began to translate our key documents into Hebrew, Spanish, and Millennial languages; established opportunities for HSD Associates to share their emerging learnings with each other and the world; and explored new business models for training and consulting to move the Institute into its next phase of development. All in all, we ventured into new and exciting territory and learned many things in the process.

We were not alone in our breakthrough journeys. Our colleagues and clients are charting new paths, as well. These complex times invite—indeed demand—that individuals and organizations break through old boundaries and explore new terrain. The only way to thrive in a turbulent environment is to move out of the comfort zone and engage across differences. In human systems dynamics, we call this "adaptive capacity." Share your insights with us online at http://hsdcommunity.ning.com/forum/topics/adaptive-capacities. For more information about HSD and our HSDP certification training, visit our website at www.hsdinstitute.org. Thank you for your support in 2010, and I hope you make 2011 a year of boundary crossing and adaptive action for yourself and your communities.



Riga

SACRED NETWORKS **Chris Hardy reports....**

Chris' book, The Sacred Network, which debuted at the SCTPLS conference in Richmond in 2008, will be published in the US this year. She has moved back to France from India.

DEAN OF NEW YORK **Larry Liebovitch located...**

Larry Liebovitch has taken a new job as Dean of Mathematics and Natural Sciences at Queens College, City University of New York. Larry spent many years on the faculty of the Center for Complex Systems at Florida Atlantic University and did a stint as its director. Thanks to Scott Kelso, Cliff Brown, and Robin Vallacher for helping us find Larry.

MEDICAL RESEARCH
From George Mpitsos

I have a very interesting idea (so it seems to me) about a method with which to screen for persons who are most likely to experience sudden unexpected cardiac death (SUCD). Have finally talked a cardiologist into gathering a data from patients in a small clinical study that's overseen by an IRB. In my experience in science, life, and physiology the most difficult thing to SEE are the most obvious ones, and this is truly obvious....

AGEAN PHOTOS
From Michael Radin ...

Mike sent photos of Riga in the Aegean Sea where he spent a good part of 2010 studying the aquatic ecology there.

CREATIVE CYBERNETICS
From Hector Sabelli...

Right now I am concentrating on a piece of work, hopefully not my swan song, which I believe will be my major contribution: *Co-creation, a scientific approach to social health*. It will be published in The Creative Cybernetics of Human Processes (Special issue of The Open Cybernetics and Systemics Journal. Edited by Sabelli and Atoor Lawandow) and I hope to present it at Winter Chaos (March 2011). I hope to make even greater progress in the New Year, particularly with a book on medicine which now has a tentative final deadline of August 2011. Last, but not least, I would like to send best wishes for a wonderful New Year to each and every one of you! I look forward to our continued friendship and collaboration into the New Year.

FLOODS IN QUEENSLAND
From Ken Ware ...

Ken sent pictures of the flooding in Queensland. He and his neighbors have a lot of cleaning up to do, unfortunately. Ken adds that the news reports we've received about snakes and crocadiles are greatly overstated.

More NEWS FROM MEMBERS next issue ...

Sunset Session

at the 21st Annual SCTPLS Conference

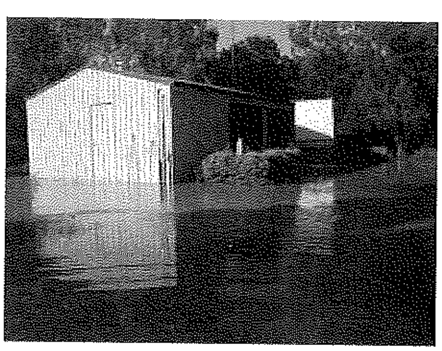
POLEMNIA G. AMAZEEN

Department of Psychology Arizona State University

Crossing Boundaries with Dynamics

Dynamical systems analysis offers a cohesive, interdisciplinary approach to science. This powerful tool comes from theoretical physics and engineering, but it can be used to analyze patterns of change in psychology and other social sciences. In this talk, I will present a strategy for dynamical application that centers on the idea of dynamical similitude: the same behaviors are observed across very different systems. That concept allows us to adopt dynamical models from outside of psychology to study the phenomena that interest us in psychology. I will show how this strategy has been used successfully in such diverse fields as motor coordination and clinical psychology. In some cases, there is no apparent model fit. I will illustrate how (social) team dynamics can be extracted using more exploratory techniques. As the dynamical literature in the social sciences grows, so do the possibilities for application and collaboration.

Biography. Polemnia G. Amazeen is an Associate Professor in the Department of Psychology at Arizona State University. She received her Ph.D. from the Center for the Ecological Study of Perception and Action at the University of Connecticut in 1996 and completed a three-year postdoctoral fellowship in the Faculty of Human Movement Sciences at the Vrije Universiteit, Amsterdam before joining the faculty at ASU in 1999. Dr. Amazeen's research is concerned with the treatment of coordination as a complex, dynamical system. She looks for general principles in coordination patterns across people (social interactions) and within people (bimanual and motor-respiratory coordination) using the tools of dynamical systems analysis. Dr. Amazeen's research is naturally collaborative. Recent projects include: the detection of team coordination patterns in real time; oscillations in pain prediction accuracy in rheumatoid arthritis patients; and dynamical analysis of dyadic interactions in elementary schoolchildren. Dr. Amazeen's work appears in over 50 articles, chapters, and published abstracts and has been presented at numerous workshops, conferences, and invited colloquia. She is a currently an Associate Editor for *Research Quarterly for Exercise and Sport* and a Consulting Editor for *Ecological Psychology*. Dr. Amazeen's research has been funded by the National Science Foundation and the Office of Naval Research.

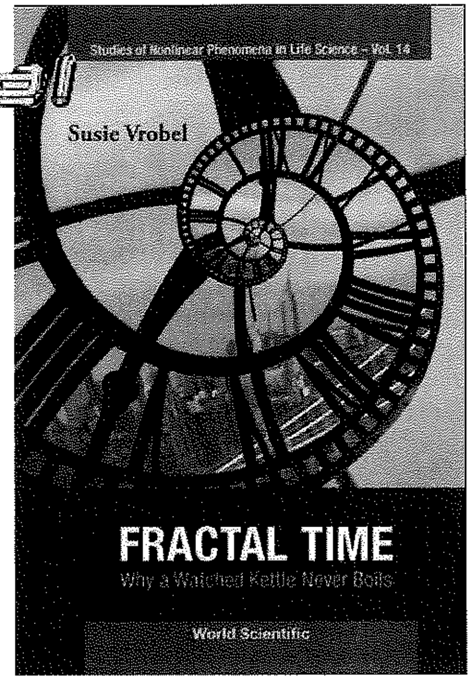


Floodwaters in Queensland

More news about the pre-conference workshop and guest speakers is scheduled for the next SCTPLS Newsletter.

Watch your e-mail meanwhile!

Nonlinear Dynamical Bookshelf



Glotzer, S. C. (2011). International assessment of research and development in simulation-based engineering and science. Singapore: World Scientic. SBE&S cuts across disciplines, showing tremendous promise in areas from storm prediction and climate modeling to understanding the brain and the behavior of numerous other complex systems. Nine distinguished leaders assess the latest research trends, as a result of 52 site visits in Europe and Asia and hundreds of hours of expert interviews, and discuss the implications of their findings for the U. S. Government.

Mansfield, J. (2010). The nature of change or the law of unintended consequences: An introductory text to designing complex systems and managing change. Singapore: World Scientific. This absorbing book provides a broad introduction to the surprising nature of change, and explains how the Law of Unintended Consequences arises from the waves of change following one simple change. Change is a constant topic of discussion whether it be climate, politics, technology or any of the many other changes in our lives. However, does anyone truly understand what change is? Unfortunately in a truly complex social or technical environment, planned predictability can break down into a morass of surprising and unexplected consequences.

Vrobel, S. (2011). Fractal Time: Why a watched pot never boils. Singapore: World Scientific. This book provides an interdisciplinary introduction to the notion of fractal time, starting from scratch with a philosophical and perceptual puzzle. How subjective duration varies, depending on the way we embed current content into contexts, is explained.

The complexity of our temporal perspective depends on the number of nestings performed, i.e. on the number of contexts taken into account. This temporal contextualization is described against the background of the notion of fractal time. Our temporal interface, the Now, is portrayed as a fractal structure which arises from the distribution of content and contexts in two dimensions: the length and the depth of time. The leitmotif of the book is the notion of simultaneity, which determines the temporal structure of our interfaces.

Recent research results are described which present and discuss a number of distorted temporal perspectives. It is suggested that dynamical diseases arise from unsuccessful nesting attempts, i.e. from failed contextualization. Successful nesting, by contrast, manifests itself in a "win-win handshake" between the observer-participant and his chosen context. The answer as to why a watched kettle never boils has repercussions in many a discipline. It would be of immense interest to anyone who works in the fields of cognitive and complexity sciences, psychology and the neurosciences, social medicine, philosophy and the arts.

Whittle, P. (2011). Neural nets and chaotic carriers (2nd ed.). Singapore: World Scientific. Develops rational principles for the design of associative memories, with a view to applying these principles to models with irregularly oscillatory operation so evident in biological and neural systems, and necessitated by the meaningfulness of absolute signal levels.

Design is based on the criterion that an associative memory must be able to cope with "fading data", i.e., to form an inference from the data even as its memory of that data degrades. The resultant net shows striking biological parallels. When these principles are combined with the Freeman specification of a neural oscillator, some remarkable effects emerge. For example, the commonly-observed phenomenon or neuronal bursting appears, with gamma-range oscillation modulated by a low-frequency square-wave osciallation (the "escapement oscillation").

Zhand, H., Liu, D., & Wang, Z. (2010). Suppression, Synchronization and Chaotification (Communications and Control Engineering). New York: Springer. Controlling Chaos offers its reader an extensive selection of techniques to achieve three goals: the suppression, synchronisation and generation of chaos, each of which is the focus of a separate part of the book. The text deals with the well-known Lorenz, Rössler and Hénon attractors and the Chua circuit, and with less celebrated novel systems. Modelling of chaos is accomplished using difference equations and ordinary and time-delayed differential equations. The methods directed at controlling chaos benefit from the influence of advanced nonlinear control theory: inverse optimal control is used for stabilization; exact linearization for synchronization; and impulsive control for chaotification. Notably, a fusion of chaos and fuzzy systems theories is employed, with the Takagi–Sugeno model and the authors' own fuzzy hyperbolic model utilized in the modelling and control of chaotic systems. Time-delayed systems are also studied with many synchronisation methods being explored. All the results presented are general for a broad class of chaotic systems.

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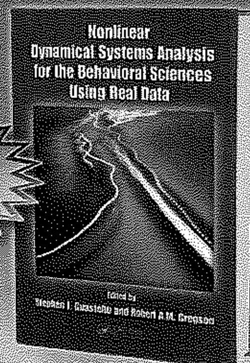
Nonlinear Dynamical Systems Analysis for the Behavioral Sciences Using Real Data



Save 20%*

Edited by
Stephen J. Guastello • Marquette University, Milwaukee, Wisconsin USA
Robert A.M. Gregson • Australian National University, Canberra

Expert insight, theoretical and practical knowledge, and new ways of framing research problems and designs

Although its roots can be traced to the 19th century, progress in the study of nonlinear dynamical systems has taken off in the last 30 years. While pertinent source material exists, it is strewn about the literature in mathematics, physics, biology, economics, and psychology at varying levels of accessibility. A compendium research methods reflecting the expertise of major contributors to NDS psychology, **Nonlinear Dynamical Systems Analysis for the Behavioral Sciences Using Real Data** examines the techniques proven to be the most useful in the behavioral sciences.

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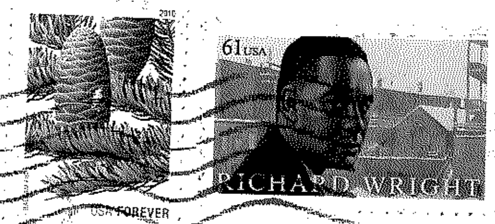

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