A HYBRID MODEL BASED ON CHAOS THEORY AND ARTIFICIAL **IMMUNE SYSTEMS FOR THE ANALYSIS AND CLASSIFICATION OF STOCK MARKET ANOMALIES**

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Abstract: In this-paper, a system for analyzing chaotic patterns in financial markets has been developed by combining classical chaos metrics with artificial immune systems for anomaly detection. Implemented indicators include the Lyapunov exponent, correlation dimension, approximate entropy, Hurst exponent, and the distance from a reference Lorenz trajectory. These metrics enable the detection of changes in market stability and predictability over time. An adaptive algorithm inspired by artificial immune systems was developed for identifying anomalous behaviors, adjusting detectors based on detected deviations. The results are presented through a series of interactive visualizations, including 3D plots, time series, and anomaly density maps. In addition to standard analysis, the system supports false alarm detection through controlled parameter variations. This approach provides deeper insights into the complex dynamics of financial markets and can serve as a tool for forecasting periods of instability.

Keywords: anomaly detection, artificial immune systems, chaos metrics, financial markets, lorenz attractor, lyapunov exponent

INTRODUCTION

The intricate and nonlinear dynamics of financial markets have long challenged researchers seeking to model, predict, and understand their behavior [1]. In particular, the emergence of chaotic patterns [2], characterized by sensitivity to initial conditions and underlying structural complexity, necessitates the development of sophisticated analytical frameworks. Within this context, quantifying chaos using dynamical system metrics—such as the Lyapunov exponent, correlation dimension, approximate entropy, and the Hurst exponent—has proven instrumental in revealing hidden order within seemingly stochastic market behavior [3,4]. This study introduces an integrated computational framework for the detection and analysis of chaotic phenomena in financial time series. By employing a combination of classical chaos theory metrics and novel bio-inspired anomaly detection techniques—specifically, artificial immune system algorithms—this work offers a robust methodology for identifying critical transitions and stability fluctuations in financial markets. The innovative incorporation of Lorenz attractor trajectory comparisons further enhances the model's sensitivity to nonlinear deviations, providing an enriched perspective on temporal evolution and emergent anomalies [5]. The proposed system facilitates both qualitative and quantitative exploration through interactive, multidimensional visualizations, encompassing 3D scatter plots, temporal evolution graphs, and anomaly density heatmaps. Within this context, two distinct adaptive immune detection models are employed to simulate varying market surveillance scenarios—one of which incorporates stochastic false alarm mechanisms to emulate noisy and unpredictable detection environments. The second model operates without false alarm mechanisms, thereby reflecting a more idealized and deterministic surveillance framework for comparative analysis. By integrating traditional

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chaos theory with quantitative classification based on dynamical system indicators—such as the Lyapunov exponent and the Hurst exponent—the presented approach aims to enhance early warning systems and predictive analytics in financial engineering.

METHODOLOGY

In this work, an innovative methodology was developed for analyzing the chaotic characteristics of capital markets by combining mathematical models, chaos-based metrics (such as the Lyapunov and Hurst exponents), and adaptive immune system-inspired detection frameworks. The analysis was carried out through a series of functional components that enable quantitative measurement of nonlinear dynamics in stock price time series, as well as anomaly detection in market behavior. Stock price data were obtained using the Yahoo Finance service, ensuring the timeliness and relevance of the time series for the purposes of the analysis. Each method used is described in detail below. The Lorenz system is a classic mathematical model that describes chaotic behavior. It was created in 1963 when meteorologist Edward Lorenz tried to model atmospheric convection [6]. A particularly notable feature of this system is its extreme sensitivity to initial conditions, where even minimal changes can lead to vastly different outcomes—a hallmark of chaotic behavior.

The Lorenz system is defined by three coupled nonlinear differential equations:

$$\frac{dx}{dt} = \sigma(y - x) \tag{1}$$

$$\frac{dy}{dt} = x(\rho - z) - y \tag{2}$$

$$\frac{dz}{dt} = xy - \beta z \tag{3}$$

Where:

x – position in space (can be seen as the system's state),

y – second coordinate (e.g., rate of change),

z – third coordinate (could represent heat or altitude in atmospheric modeling) [7];

Parameters that control the system's behavior:

 σ =10(Prandtl number – measures the ratio of viscosity to thermal diffusivity),

 ρ =28(Rayleigh number – measures temperature difference),

 β =83(geometric factor – depends on the system's shape);

When these parameters are set to these values, the Lorenz system exhibits pure chaotic behavior — the famous "Lorenz attractor"[8].

Numerical solutions were obtained using the variable-step integration method via the solve_ivp function, with initial conditions $(x_0, y_0, z_0) = (1.0, 1.0, 1.0)$ and a time step of dt = 0.01. The resulting trajectory consists of state vectors (x(t), y(t), z(t)) at each discrete time point, allowing the creation of a representative pattern of chaotic behavior. After generating the Lorenz trajectory, a function was developed to quantify the similarity between the real-time series of market prices and the reference chaotic trajectory. The market price time window and the x-component of the Lorenz trajectory were independently normalized using standard Z-score normalization:

$$u_{norm} = \frac{u - \mu_u}{\sigma_u + 10^{-8}},\tag{4}$$

where represents the mean, and the standard deviation of the observed series [9]. Normalization removes the influence of absolute scale, enabling a focus purely on fluctuation patterns.

The similarity between the normalized sequences was then measured using the Euclidean norm:

$$d(u,v) = \sqrt{\sum_{i=1}^{m} (u_i - v_i)^2},$$
 (5)

where m is the length of the shorter of the two compared sequences. This metric quantifies the global distance between the two signals, where lower distance values indicate a higher degree of similarity, i.e., a stronger chaotic resemblance between the market window and the Lorenz attractor [10]. In this way, a robust method was created for detecting latent chaotic dynamics within time series of market prices [11]. The choice of the Lorenz system as a reference model is justified by its ability to exhibit extremely sensitive and nonlinear behavior despite its deterministic nature, providing a valid benchmark for comparison with real-world market processes [12].

In this study, four key metrics were applied to quantify chaotic behavior in time series: Approxi-

mate Entropy, Hurst Exponent, Maximal Lyapunov Exponent, and Correlation Dimension. Each of these metrics provides a specific perspective on the internal complexity and predictability of temporal processes.

Approximate Entropy (ApEn) measures the regularity and unpredictability of fluctuations in a time series [13]. Formally, ApEn is defined as:

$$ApEn(m,r) = \phi(m) - \phi(m+1)$$
(6)

where:

$$\phi(m) = \frac{1}{N-m+1} \sum_{i=1}^{N-m+1} \ln C_i^m(r)$$
(7)

Here, $C_i^m(r)$ represents the proportion of vectors of length mmm that are within a distance *r* from the reference vector x(i). The threshold *r* is usually chosen as a percentage of the standard deviation of the time series.

The distance between two vectors is measured by the maximum absolute difference between their respective components [14].

$$d(x(i), x(j)) = \max_{k=1, 2, \dots, m} |x(i+k-1) - x(j+k-1)|$$
(8)

Higher values of Approximate Entropy indicate lower predictability and greater chaos within the system.The Hurst Exponent is a measure of long-term memory in a time series [15]. Its interpretation is as follows:

- H=0.5: The process is a random walk (memoryless),
- H>0.5H: Positive autocorrelation (trending behavior),
- H<0.5H: Negative autocorrelation (mean-re-verting behavior).

Hurst's relation is expressed through the rescaled range analysis:

$$E[R(n)/S(n)] \propto n^H \tag{9}$$

where R(n) is the range of cumulative deviations, S(n) is the standard deviation, and nnn is the length of the subseries.

The Maximal Lyapunov Exponent measures the rate of divergence between initially close trajectories in the phase space [16]. Formally:

$$\lambda max = \lim_{t \to \infty} \frac{1}{t} ln \frac{d(t)}{d(0)},$$
(10)

where d(0) and d(t) are the initial and evolved distances between two nearby points, respectively.

The Correlation Dimension estimates the fractal complexity of a system [17]. It is defined through the correlation function C(r) as:

$$C(r) = \lim_{N \to \infty} \frac{2}{N(N-1)} \sum_{i < j} \Theta(r - ||x_i - x_j||$$
(11)

where Θ is the Heaviside step function, and *r* is the distance threshold. In practice, the correlation dimension D_2 is approximated as:

$$D_2 \approx \frac{dlnC(r)}{dlnr} \tag{12}$$

For calculation, the distance matrix between reconstructed phase space vectors is generated, and the number of vector pairs with distances less than ris counted, providing an insight into the complexity of the dynamical system [18].

The Artificial Immune System (AIS) is inspired by the biological immune system and is utilized for anomaly detection in complex datasets. Two versions of the AIS algorithm were used here: without false alarms and with false alarms, both based on reactive cloning of detectors [19]. For a dataset $X = \{x1, x2, ..., xN\}$ where each vector instance is defined as:

the features are first standardized:

$$z_i = \frac{x_i - \mu}{\sigma} \tag{14}$$

where and are the vectors of mean values and standard deviations of the individual features.

The formulation with false alarms is:

Anomaly =
$$(\min_{i} di > \theta) \lor (rand() < pfalse)(15)$$

where *rand ()* is a uniformly random value from the interval [0,1].

RESULTS

In this study, we analyzed the chaotic dynamics of the stock prices of major technology companies (AAPL, MSFT, GOOGL, NVDA, INTC, AMD, and IBM) [20, 21] using a set of nonlinear time series metrics. The analysis covered the period from January 1, 2020, to April 3, 2025. For each company's closing price time series, a sliding window approach was used with a window size of

$$W = 200$$
 (16)

samples and a step size of S = 20. Within each window, the following metrics were calculated:

- Maximum Lyapunov Exponent (λmax), indicating sensitivity to initial conditions.
- Correlation Dimension (D_2) , measuring the fractal complexity of the trajectory.
- Approximate Entropy (ApEn), evaluating the unpredictability of the system.
- Hurst Exponent (H), indicating long-term memory and trend persistence.
- Lorenz Distance (d_{Lorenz}), comparing the real data to the reference Lorenz attractor.

The calculated features were then passed through the Artificial Immune System (AIS) algorithm for anomaly detection. Two AIS versions were tested: Normal AIS without induced false alarms, AIS with False Alarms, which introduces 5% random anomalies to simulate realistic detection imperfections. Additionally, each time window was classified into one of several market states based on threshold conditions over the Lyapunov exponent and Hurst exponent. Classification of Market States Based on Lyapunov and Hurst Exponents (Table 1) [22].

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Highly Unstable

Table 1. Summary of Quantitative Data for Apple Inc.				
Lyapunov	Hurst	Market State		
λ>0.3	H<0.3	Very Chaotic		
0.1<λ≤0.30	H<0.4	Chaotic		
λ<0.05	H>0.7	Highly Predictable		
λ<0.1	0.5≤H≤0.70	Stable		
0.05≤λ≤0.2	0.4≤H≤0.6	Semi-Stable		

otherwise

otherwise

A series of visualizations was generated to illustrate the behavior and evolution of chaotic metrics across time for selected stock market symbols. These include time-series plots of individual metrics (Lyapunov exponent, correlation dimension, approximate entropy, Hurst exponent, and Lorenz distance), a 3D scatter plot of the Lyapunov–Correlation Dimension–Lorenz Distance space, as well as anomaly detection visualizations such as heatmaps and scatter diagrams. These visual analyses reveal transitions between different market states and highlight the artificial immune system's effectiveness in identifying anomalies, even when false alarms are introduced, such as during periods of heightened volatility (e.g., the 2020 pandemic shock). The following images show the results for Apple (Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5)

Time	Lyapunov	CorrDim	proxEntro	Hurst	LorenzDist	Anomaly	AnomalySt	MarketStath	omalvNu
2020-10-1		-2,1976	0,34375	0,79571	457,082	FALSE	Normal	Highly Un:	0
2020-11-1	0,55553	-2,3307	0,36797	0,78121	457,082	FALSE	Normal	Highly Un:	0
2020-12-1		-2,2752	0,3324	0,80563	457,082	FALSE	Normal	Highly Un:	0
2021-01-1		-2,318	0,35487	0,85975	457,082	FALSE	Normal	Highly Un:	0
2021-02-1		-2,4358	0,40324	0,80464	457,082	FALSE	Normal	Highly Un:	0
2021-03-1		-2,6871	0,55594	0,70303	457,082	FALSE	Normal	Highly Un:	0
2021-04-1		-2,9484	0,69205	0,6153	457,082	FALSE	Normal	Highly Un	ō
2021-05-1		-3,2935	0,79913	0,57356	457,082	FALSE	Normal	Highly Un:	0
2021-06-0		-3,706	0,88305	0,44629	457,082	FALSE	Normal	Highly Un	0
2021-07-0		-3,4778	0,85138	0,50773	457,082	FALSE	Normal	Highly Un:	ō
2021-08-0		-3,2195		0,51714	457,082	FALSE	Normal	Highly Un	ō
	0,20766	-3,0205	0,7026	0,53207	457,082	FALSE	Normal	Highly Un	ō
2021-09-3	-	-2,9285	0,69084	0,52385	457,082	FALSE	Normal	Semi-Stat	ő
2021-10-2		-2,8634	0,64578	0,57001	457,082	FALSE	Normal	Semi-Stat	o
2021-10-2		-2,604	0,57023	0,58573	457,082	FALSE	Normal	Semi-Stat	0
2021-11-2		-2,3124	0,42398	0,68238	457,082	FALSE	Normal		0
2021-12-2		-2,5124	0,42598	0,08258	457,082	FALSE		Highly Un: Highly Un:	0
		-2,2495	0,41762	0,70994	457,082	FALSE	Normal	Highly Un:	0
2022-02-2							Normal	Highly Un:	0
2022-03-2		-2,576	0,56611	0,63136	457,082	FALSE	Normal	Highly Un:	0
2022-04-2		-2,769	0,67216	0,5023	457,082	FALSE	Normal	Highly Un:	0
2022-05-1		-3,0939	0,75499	0,48007	457,082	FALSE	Normal	Highly Un:	0
2022-06-1	0,55581	-3,1683 -3,1028	0,72412	0,50075	457,082	FALSE	Normal	Highly Un:	0
					457,082			Highly Un:	0
	0,60588	-3,3821	0,77552	0,4859		FALSE	Normal	Highly Un:	0
2022-09-1		-3,397	0,79571	0,47893	457,082	FALSE	Normal	Highly Un:	0
	0,61928	-3,4412	0,81961	0,49588	457,082	FALSE	Normal	Highly Un:	
-	0,63459	-3,6147	0,84956	0,48084	457,082	FALSE	Normal	Highly Un:	0
2022-12-0		-3,6899	0,87353	0,46445	457,082	FALSE	Normal	Highly Un:	0
2023-01-0		-3,4697	0,83232	0,51093	457,082	FALSE	Normal	Highly Un:	0
2023-02-0		-3,6642	0,87401	0,47972	457,082	FALSE	Normal	Highly Un:	0
2023-03-0		-3,5225	0,86592	0,47583	457,082	FALSE	Normal	Highly Un:	0
2023-04-0		-3,4444	0,81832	0,52233	457,082	FALSE	Normal	Highly Un:	0
2023-05-0		-3,3249	0,77097	0,53153	457,082		Normal	Highly Un:	0
2023-06-0		-3,1005	0,68284	0,57694	457,082	FALSE	Normal	Highly Un:	0
2023-07-0		-2,7762	0,55925	0,63977	457,082	FALSE	Normal	Highly Un:	0
2023-08-0		-2,5793	0,42076	0,66876	457,082	FALSE	Normal	Highly Un:	0
2023-08-2		-2,5405	0,3582	0,71933	457,082	FALSE	Normal	Highly Un:	0
2023-09-2		-2,4995	0,38044	0,7616	457,082		Normal	Highly Un:	0
2023-10-2		-2,4965	0,40877	0,73271	457,082	FALSE	Normal	Highly Un:	0
2023-11-2		-2,7284	0,55107	0,65626	457,082	FALSE		Highly Un:	0
2023-12-2		-2,8138	0,57995	0,63599	457,082	FALSE	Normal	Highly Un:	
2024-01-2		-3,095	0,70483	0,50851	457,082	TRUE		Highly Un:	1
2024-02-2		-3,2669	0,78332	0,43129	457,082	FALSE	Normal	Semi-Stat	
2024-03-2		-3,397	0,81478	0,38629	457,082	FALSE	Normal	Chaotic	0
2024-04-1		-3,2669	0,79853	0,39379	457,082	FALSE	Normal	Chaotic	0
2024-05-1		-3,3999	0,79234	0,3784	457,082	FALSE	Normal	Chaotic	0
2024-06-1		-3,0786	0,72035	0,47607	457,082	FALSE	Normal	Highly Un:	0
2024-07-1		-2,441	0,51908	0,5555	457,082	FALSE	Normal	Highly Un:	0
2024-08-1		-2,3169	0,47883	0,6317	457,082	FALSE	Normal	Highly Un:	0
2024-09-1		-2,2944	0,43547	0,65063	457,082	FALSE	Normal	Highly Un:	0
-	0,54965	-2,2526	0,42121	0,60915	457,082	FALSE	Normal	Highly Un:	0
2024-11-0		-2,2143	0,39217	0,59774	457,082	FALSE	Normal	Highly Un:	0
	0,61316	-2,0327	0,35441	0,68222	457,082	FALSE	Normal	Highly Un:	0
2025-01-0		-2,1011	0,37317	0,71007	457,082	FALSE	Normal	Highly Un:	0
	0,76423	-2,3541	0,5049	0,75331	457,082	FALSE	Normal	Highly Un:	0
	0,66032	-2,8704	0,69222 0,84517	0,58978	457,082	FALSE	Normal	Highly Un: Highly Un	0
2025-04-0	0,59575	-3,4196	0,04517	0,41427	457,082	PALSE	Normal	Highly Un:	0

Figure 1. Summary of Quantitative Data for Apple Inc.

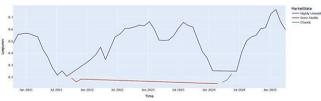


Figure 2. APPL Evaluation of Market State

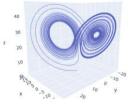
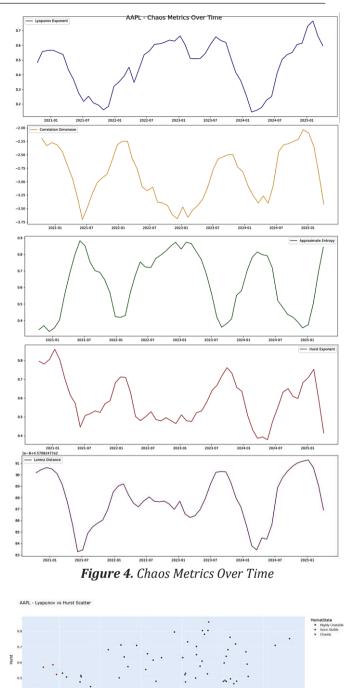


Figure 3. Lorenz Attractor Reference



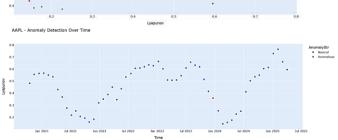


Figure 5. Lyapunov vs Hurst Scatter and Anomaly Detection over Time for Apple Inc.

The following images show the results for Microsoft. (Figure 6, Figure 7, Figure 8, Figure 9 and Figure 10).

Time Lyapunov CorrDim ApproxEntr		
0 2020-10-15 0.984298 -2.682017	0.570056 0.585099 457.082478 False Normal Highly Unstable	0
1 2020-11-13 0.998497 -2.701199	0.611944 0.593761 457.082478 False Normal Highly Unstable	0
2 2020-12-14 0.920345 -2.515469	0.570249 0.648166 457.082478 False Normal Highly Unstable	0
3 2021-01-13 0.751093 -2.764224	0.675680 0.661012 457.082478 False Normal Highly Unstable	0
4 2021-02-11 0.689598 -2.934167	0.724048 0.598357 457.082478 False Normal Highly Unstable	0
5 2021-03-12 0.701985 -3.142494	0.804076 0.533935 457.082478 False Normal Highly Unstable	0
6 2021-04-12 0.650508 -3.194793	0.825943 0.484882 457.082478 False Normal Highly Unstable	0
7 2021-05-10 0.712619 -2.921089	0.729886 0.474338 457.082478 False Normal Highly Unstable	0
8 2021-05-08 0.733561 -2.964718	0.689436 0.517207 457.082478 True Anomalous Highly Unstable	1
9 2021-07-07 0.767630 -2.710929	0.530177 0.613295 457.082478 False Normal Highly Unstable	0
10 2021-08-04 0.799445 -2.491629	0.436138 0.671190 457.082478 False Normal Highly Unstable	0
11 2021-09-01 0.853220 -2.432409	0.338486 0.738178 457.082478 False Normal Highly Unstable	0
12 2021-09-30 0.901489 -2.485507	0.356349 0.736367 457.082478 False Normal Highly Unstable	0
13 2021-10-28 0.915244 -2.450702	0.366667 0.752828 457.082478 False Normal Highly Unstable	0
14 2021-11-26 0.951830 -2.327647	0.285807 0.740972 457.082478 False Normal Highly Unstable	0
15 2021-12-27 0.998164 -2.353089	0.302287 0.794351 457.082478 False Normal Highly Unstable	0
16 2022-01-25 0.988753 -2.450215	0.384785 0.730161 457.082478 False Normal Highly Unstable	0
17 2022-02-23 1.037871 -2.599981	0.502917 0.708916 457.082478 False Normal Highly Unstable	0
18 2022-03-23 0.981474 -2.900877	0.645844 0.619015 457.082478 False Normal Highly Unstable	ō
19 2022-04-21 0.894979 -3.145974	0.848138 0.456487 457.082478 False Normal Highly Unstable	ō
20 2022-05-19 1.019042 -3.141335	0.779832 0.482120 457.082478 False Normal Highly Unstable	ŏ
21 2022-05-17 1.143725 -3.056591	0.701566 0.555545 457.082478 False Normal Highly Unstable	0
22 2022-07-19 1.195809-3.074235	0.707257 0.544714 457.082478 False Normal Highly Unstable	0
23 2022-08-16 1.216830 -3.041253	0.719884 0.553879 457.082478 False Normal Highly Unstable	ŏ
24 2022-09-14 1.225081 -3.286753	0.765167 0.505864 457.082478 False Normal Highly Unstable	ŏ
25 2022-10-12 1.225081-5.285755	0.755602 0.538620 457.082478 False Normal Highly Unstable	0
		0
26 2022-11-09 1.234830 -3.442801 27 2022-12-08 1.210547 -3.450152		0
		_
28 2023-01-09 1.162100 -3.354552	0.758508 0.555709 457.082478 False Normal Highly Unstable 0.843838 0.459868 457.082478 False Normal Highly Unstable	0
29 2023-02-07 1.049384 -3.594479		0
30 2023-03-08 0.993452 -3.650521		
31 2023-04-05 1.003873 -3.466536		0
32 2023-05-04 1.074885 -3.141336	0.742652 0.514793 457.082478 True Anomalous Highly Unstable 0.625510 0.607650 457.082478 False Normal Highly Unstable	
33 2023-05-02 1.149076 -2.682748		0
34 2023-07-03 1.202703 -2.321513	0.489533 0.699241 457.082478 False Normal Highly Unstable	0
35 2023-08-01 1.290793 -2.340547	0.422638 0.723780 457.082478 False Normal Highly Unstable	0
36 2023-08-29 1.250200 -2.336918	0.395311 0.746010 457.082478 False Normal Highly Unstable	0
37 2023-09-27 1.265569 -2.299340	0.386631 0.736183 457.082478 False Normal Highly Unstable	0
38 2023-10-25 1.204165 -2.250704	0.432721 0.750561 457.082478 False Normal Highly Unstable	0
39 2023-11-22 1.202694 -2.340027	0.452886 0.747497 457.082478 False Normal Highly Unstable	0
40 2023-12-21 1.175137 -2.416034	0.454924 0.765458 457.082478 False Normal Highly Unstable	0
41 2024-01-23 1.111447 -2.441560	0.470068 0.714646 457.082478 False Normal Highly Unstable	0
42 2024-02-21 1.124517 -2.311374	0.468566 0.630300 457.082478 False Normal Highly Unstable	0
43 2024-03-20 1.130141 -2.205139	0.437044 0.656068 457.082478 False Normal Highly Unstable	0
44 2024-04-18 1.173874 -2.182804	0.366677 0.682638 457.082478 False Normal Highly Unstable	0
45 2024-05-16 1.145041 -2.120889	0.348884 0.705774 457.082478 False Normal Highly Unstable	0
45 2024-05-14 1.148405 -2.200254	0.380316 0.712386 457.082478 True Anomalous Highly Unstable	1
47 2024-07-16 1.253697 -2.283518	0.382470 0.759977 457.082478 False Normal Highly Unstable	0
48 2024-08-13 1.234515 -2.610130	0.519382 0.753948 457.082478 False Normal Highly Unstable	0
49 2024-09-11 1.085105 -2.881055	0.676735 0.601865 457.082478 False Normal Highly Unstable	0
50 2024-10-09 1.087597 -3.270827	0.823788 0.561699 457.082478 False Normal Highly Unstable	0
51 2024-11-05 0.974305 -3.631554	0.902828 0.461063 457.082478 False Normal Highly Unstable	0
52 2024-12-05 0.949707 -3.612845	0.933565 0.468615 457.082478 False Normal Highly Unstable	0
53 2025-01-05 0.972903 -3.587226	0.878578 0.460124 457.082478 False Normal Highly Unstable	0
54 2025-02-05 1.010847 -3.609144	0.862471 0.439534 457.082478 False Normal Highly Unstable	0
55 2025-03-05 0.988234 -3.529315	0.849170 0.426025 457.082478 False Normal Highly Unstable	0
56 2025-04-03 1.111512 -3.280087	0.797710 0.476636 457.082478 False Normal Highly Unstable	0

Figure 6. Summary of Quantitative Data for Microsoft Inc.

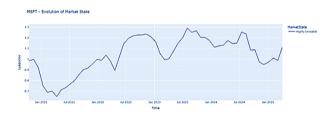
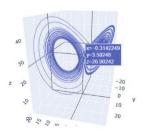
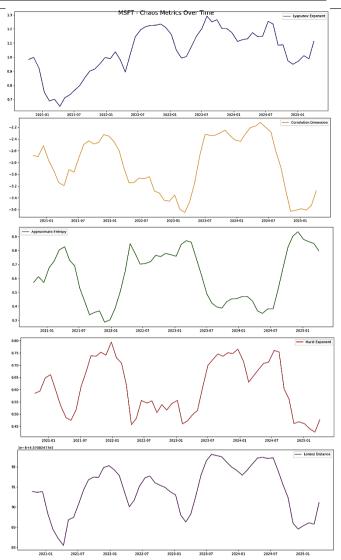


Figure 7. Evaluation of Market State







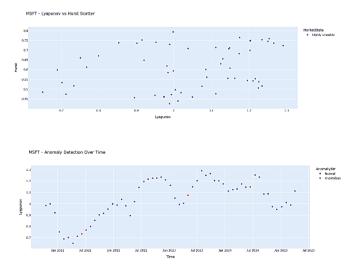


Figure 10. Lyapunov vs Hurst Scatter and Anomaly Detection over Time for Microsoft Inc.

Figure 8. Lorenz Attractor Reference

The following images show the results for Google (Figure 11, Figure 12, Figure 13, Figure 14 and Figure 15)

2 020-10-16-0.182:009-2.651788 0.613614 0.596957 457.082478 True Anomalous Stable 0 2 020-11-13-0.059585 0.60382 0.60382 0.60382 457.082478 False Normal Stable 0 2 020-12-14-0.000017 0.569485 0.499421 0.669283 457.082478 False Normal Highly Predictable 3 021-02-11-0.12109-2.35791 0.451272 0.73040 457.082478 False Normal Highly Predictable 0 5 021-04-12-0.055863-2.05218 0.339831 0.7306800 457.082478 False Normal Highly Predictable 0 3 021-05-00 0.055683-2.052812 0.251969 0.857764277 False Normal Highly Instable 0 0 0.26922 0.85964 Normal Highly Unstable 0 0 11001-0001 0.116005-2.11543 0.229827 0.839457.082478 False Normal Highly Unstable 12021-10-28 0.116919-2.21640 0.322020 7.63977.082478 False Normal Highly Unstable 12021-10-28	Line Lyamanov CorrDin America				
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15 2024-05-16 0.288483-2.626585 0.602744 0.513137 457.082478 False Normal High'y Unstable 16 2024-06-14 0.361842 -2.321513 0.436113 0.588431 457.082478 False Normal High'y Unstable 16 2024-06-14 0.508250 2.371844 0.68223 457.082478 False Normal High'y Unstable 18 2024-06-13 0.598218 -2.51246 0.48335 0.54358 457.082478 False Normal High'y Unstable 18 2024-06-13 0.598128 -2.51246 0.483353 0.634358 457.082478 False Normal High'y Unstable 19/2024-06-10 0.558191 0.652188 457.082478 False Normal High'y Unstable 19/2024-06-09 0.552082 0.559799 0.625188 457.082478 False Normal High'y Unstable 12/2024-12-05 0.522342 -265021 0.666526 0.65206 0.567705 477.082478 False Normal	3 2024-03-20 0.167769 -3.274785	0.769261 0.514490 457.082478	False Norma	Semi-Stable	
45 2024-05-16 0.286483 - 2.625585 0.602744 0.513137 47.062478 False Normal Highly Unstable 16 2024-06-14 0.361842 - 2.32151 0.436115 0.588431 457.082478 False Normal Highly Unstable 17 2024-07-16 0.508230 - 2.283028 0.371844 0.662423 457.082478 False Normal Highly Unstable 18 2024-06-13 0.598238 - 2.512381 0.399950 0.688089 457.082478 False Normal Highly Unstable 18 2024-06-10 0.594113 - 2.72446 0.48333 0.654388 457.082478 False Normal Highly Unstable 19 2024-06-10 0.594113 - 2.730440 0.559799 0.625188 457.082478 False Normal Highly Unstable 50 2024-10-09 0.550892 - 2.836594 0.559799 0.625188 457.082478 False Normal Highly Unstable 51 2024-11-06 0.332919 - 2.830642 0.58250 0.6230478 0.57.082478 False Normal Highly Unstable 52 2024-12-05 0.522347 - 2.860540 0.663895 0.521930 457.082478 False Normal Highly Unstable 53 2025-01-06 0.475645-3.026707 0.663895 0.521930 457.082478 False Normal Highly Unstable 54 2025-02-05 0.523574 - 2.869540 0.618642 0.567775	44 2024-04-18 0.235523 -3.051338	0.718282 0.513845 457.082478	False Norma	Highly Unstable	
16 2024-05-14 0.361842-2.321513 0.436115 0.588431 457.082478 False Normal High yunstable 17 2024-07-16 0.508250-2.283028 0.371844 0.662423 457.082478 False Normal High yunstable 18 2024-0613 0.599238-2.512810 0.399950 0.685089 457.082478 False Normal High yunstable 18 2024-0613 0.599238-2.512810 0.399950 0.685089 457.082478 False Normal High yunstable 19 2024-09-11 0.594113-2.729145 0.483335 0.6534388 457.082478 False Normal High yunstable 19 2024-09-11 0.594113-2.729145 0.559799 0.625188 457.082478 False Normal High yunstable 10 2024-10-09 0.550892 - 2.835594 0.559799 0.625186 457.082478 False Normal High yunstable 12 2024-10-60 0.535919-2.4856021 0.60662 0.652209 457.082478 False Normal High yunstable 13 2025-01-06 0.475445-3.025707 0.6518642 0.557705 457.082478 False Normal High yunstable 14 2025-025 0.523574-2.865021 0.618642 0.567705 457.082478 False Normal High yunstable 13 2025-01-06 0.475445-3.020707 0.518542 0.567754 457.082478 <t< td=""><td>15 2024-05-16 0.288483 -2.626585</td><td>0.602744 0.513137 457.082478</td><td>False Norma</td><td></td><td></td></t<>	15 2024-05-16 0.288483 -2.626585	0.602744 0.513137 457.082478	False Norma		
17 2024-07-16 0.508250-2.283028 0.371844 0.652423 457.082478 False Normal Highly Unstable 18 2024-06-13 0.599258-2.512381 0.399950 0.688059 457.082478 False Normal Highly Unstable 18 2024-06-10 0.5991328-2.512381 0.399950 0.658059 457.082478 False Normal Highly Unstable 19 2024-06-11 0.594133-2.51246 0.483335 0.654388 457.082478 False Normal Highly Unstable 10 2024-10-09 0.550290 0.525188 457.082478 False Normal Highly Unstable 12 2024-12-05 0.522342 0.552920 0.624950 457.082478 False Normal Highly Unstable 12 2024-12-05 0.522342 0.56652 0.65290 457.082478 False Normal Highly Unstable 13 2025-01-06 0.475643-3.026707 0.653859 0.521930 457.082478 False Normal Highly Unstable 14 2025-02-05 0.523574-2.8695040 0.618642 0.567705 <td< td=""><td></td><td></td><td></td><td></td><td></td></td<>					
Bit 2024-09-13 0.59928-2.51231 0.399900 0.658059 457.082478 False Normal High y unstable 92024-09-11 0.59692 2.85594 0.483335 0.634388 457.082478 False Normal High y unstable 92024-09-11 0.550892 2.85594 0.55979 0.625188 457.082478 False Normal High y unstable 92024-10-90 0.550892 2.85594 0.559790 0.625188 457.082478 False Normal High y unstable 92024-10-90 0.532542 0.5582520 0.624950 457.082478 False Normal High y unstable 92024-12-05 0.522242 .65825021 0.656520 0.656520 0.653652 0.653659 0.521930 457.082478 False Normal High y unstable 92025-01-06 0.4375643-3.026707 0.618642 0.567705 457.082478 False Normal High y unstable 92025-02-05 0.544741 3.011354 0.6618242 0.567705 457.082478 False N					
19 2024-09-11 0.594113-2.729145 0.483335 0.634388 457.082478 False Normal Highly Unstable 02024-01-009 0.550892 2.835594 0.559799 0.625188 457.082478 False Normal Highly Unstable 102024-10-60 0.5350192 0.625220 0.624502 0.528220 62457082478 False Normal Highly Unstable 502024-12-05 0.532234 2.856021 0.606622 0.622200 624390 False Normal Highly Unstable 522024-12-05 0.522374 2.856021 0.606622 0.522309 457.082478 False Normal Highly Unstable 532025-01-06 0.475643 -3.025707 0.653895 0.521930 457.082478 False Normal Highly Unstable 42025-02-05 0.523574 -2.869540 0.618642 0.567705 457.082478 False Normal Highly Unstable 52025-03-06 0.544741 3.011354 0.684325 0.584754 457.082478 False Normal					
50 2024-10-09 0.550892-2.836594 0.559799 0.625188 457.082478 False Normal Highly Unstable 12 024-11-06 0.535919-2.830642 0.58220 0.624890 457.082478 False Normal Highly Unstable 20 204-12-05 0.522342 A550620 0.6505820 0.6505820 Normal Highly Unstable 32 025-01-06 0.475643-3026707 0.653895 0.521390 457.082478 False Normal Highly Unstable 42 025-02-05 0.4255642 0.663895 0.521390 457.082478 False Normal Highly Unstable 52 025-03-05 0.447614-3.011354 0.684325 0.5647705 457.082478 False Normal Highly Unstable 52 025-03-05 0.544741-3.011354 0.684325 0.564754 457.082478 False Normal Highly Unstable				- · ·	-
51 2024-11-06 0.535919-2.830642 0.582920 0.624950 457.082478 False Normal Highly Unstable 52 2024-12-05 0.522234-2.856021 0.606562 0.652309 457.082478 False Normal Highly Unstable 53 2025-01-06 0.475645-3.026707 0.663895 0.521930 457.082478 False Normal Highly Unstable 54 2025-025 0.523574-2.869540 0.6648842 0.567705 457.082478 False Normal Highly Unstable 55 2025-03-06 0.542474 -3.011354 0.664325 0.584754 False Normal Highly Unstable					
S2 2024-12-05 0.522234-2.656021 0.606662 0.652309 457.082478 False Normal Highly Unstable S3 2025-01-06 0.475643-3.025707 0.653895 0.521930 457.082478 False Normal Highly Unstable S4 2025-02-05 0.523574-2.669540 0.618642 0.567705 457.082478 False Normal Highly Unstable S5 2025-02-06 0.542474 1.3011354 0.66825 0.584754 457.082478 False Normal Highly Unstable					
53 2025-01-06 0.475645 -3.026707 0.663895 0.521930 457.082478 False Normal Highly Unstable 54 2025-02-05 0.523574 -2.869540 0.618642 0.567705 457.082478 False Normal Highly Unstable 55 2025-03-06 0.544741 -3.011354 0.6684325 0.584754 457.082478 False Normal Highly Unstable					_
54 2025-02-05 0.523574 -2.869540 0.618642 0.567705 457.082478 False Normal Highly Unstable 55 2025-03-06 0.544741 -3.011354 0.684325 0.584754 457.082478 False Normal Highly Unstable					
55 2025-03-05 0.544741-3.011354 0.684325 0.584754 457.082478 False Normal Highly Unstable					
10 2023-04-05 0.562570-2.946466 0.698706 0.577857 457.082478 Faise Normal Highly Unstable					
	10 2025-04-03 0.582570 -2.946466	0.698/05 0.577857 457.082478	False Norma	Highly Unstable	

Figure 11. Summary of Quantitative Data for Google Inc.

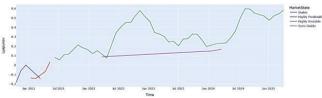


Figure 12. Evaluation of Market State

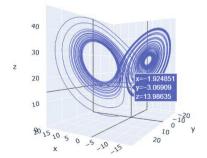


Figure 13. Lorenz Attractor Reference

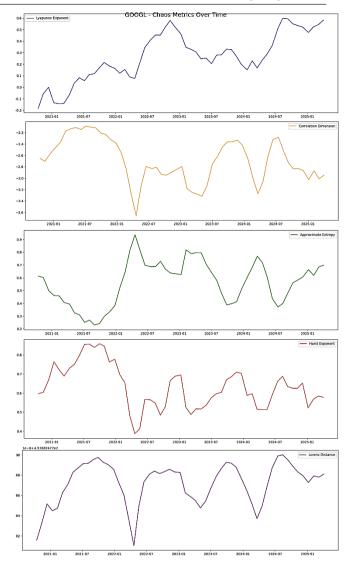


Figure 14. Chaos Metrics Over Time

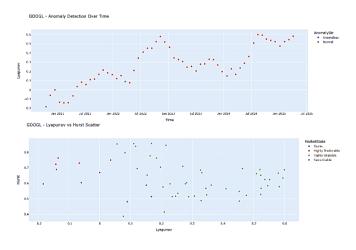


Figure 15. Lyapunov vs Hurst Scatter and Anomaly Detection over Time for Google Inc.

The following images show the results for Nvidia (Figure 16, Figure 17, Figure 18, Figure 19 and Figure 20).

Figure 16. Summary of Quantitative Data for Nvidia Inc.

Time Lyapunov CorrDin Appr		
0 2020-10-15 -1.516418 -2.228638	0.308307 0.809663 457.082478 False Normal Highly Predictable	0
1 2020-11-13 -1.414973 -2.367390	0.356005 0.812027 457.082478 True Anomalous Highly Predictable	
2 2020-12-14 -1.454680 -2.300338	0.339900 0.860766 457.082478 False Normal Highly Predictable	0
3 2021-01-13 -1.595619 -2.158701	0.348882 0.855195 457.082478 False Normal Highly Predictable	0
4 2021-02-11 -1.679495 -2.162606	0.441890 0.785348 457.082478 False Normal Highly Predictable	0
5 2021-03-12 -1.667840 -2.483807	0.583033 0.676208 457.082477 False Normal Stable 0	
6 2021-04-12 -1.728801 -2.844300	0.751239 0.621360 457.082477 False Normal Stable 0	
7 2021-05-10 -1.704675 -3.220753	0.798819 0.530165 457.082477 False Normal Stable 0	
8 2021-05-08 -1.727176 -3.350267	0.814043 0.460051 457.082477 False Normal Highly Unstable	0
9 2021-07-07 -1.593036 -2.284009	0.627728 0.578418 457.082477 False Normal Stable 0	
10 2021-08-04 -1.509227 -1.995020		D
11 2021-09-01 -1.396544 -1.907675	0.374701 0.710051 457.082478 False Normal Highly Predictable	0
12 2021-09-30 -1.281497 -2.104349	0.365668 0.728695 457.082478 False Normal Highly Predictable	0
13 2021-10-28 -1.159940 -2.291398	0.379151 0.745410 457.082478 False Normal Highly Predictable	0
14 2021-11-25 -0.942138 -2.128002	0.256859 0.826054 457.082478 False Normal Highly Predictable	0
15 2021-12-27 -0.836678 -2.154812	0.289842 0.911811 457.082478 False Normal Highly Predictable	0
16 2022-01-25 -0.778259 -2.259765	0.345118 0.843460 457.082478 False Normal Highly Predictable	0
17 2022-02-23 -0.703317 -2.454863	0.425344 0.803969 457.082478 False Normal Highly Predictable	0
18 2022-03-23 -0.746869 -2.595280	0.574134 0.641656 457.082478 False Normal Stable (D
19 2022-04-21 -0.729123 -2.787499	0.674740 0.608298 457.082478 False Normal Stable (D
20 2022-05-19 -0.625910 -2.853389	0.684790 0.595312 457.082478 False Normal Stable (D
21 2022-05-17 -0.553070 -2.971528		D
22 2022-07-19 -0.485207 -2.974450		D
23 2022-08-16 -0.505055 -2.794017		D
24 2022-09-14 -0.517700 -2.708575	0.553452 0.705523 457.082478 False Normal Highly Predictable	0
25 2022-10-12 -0.600521 -2.714597	0.517693 0.705714 457.082478 False Normal Highly Predictable	0
26 2022-11-09 -0.685207 -2.704930	0.566237 0.751550 457.082478 False Normal Highly Predictable	ō
27 2022-12-08 -0.765018 -2.691562	0.583979 0.768341 457.082478 False Normal Highly Predictable	ŏ
28 2023-01-09 -0.879903 -2.797291	0.640982 0.771222 457.082478 False Normal Highly Predictable	ŏ
29 2023-02-07 -1.026633 -3.502400		
30 2023-03-08 -0.939865 -3.075317		0
31 2023-04-05 -0.822256 -2.602002	0.502234 0.738440 457.082478 False Normal Highly Predictable	0
32 2023-05-04 -0.785178 -2.378657	0.413399 0.807818 457.082478 False Normal Highly Predictable	ő
33 2023-05-02 -0.630976 -2.136012	0.291772 0.882697 457.082478 False Normal Highly Predictable	0
34 2023-07-03 -0.516774 -2.018345		0
35 2023-08-01 -0.389524 -2.032749	0.174074 1.038478 457.082478 False Normal Highly Predictable	0
36 2023-08-29 -0.383713 -1.990881	0.205969 0.960089 457.082478 False Normal Highly Predictable	0
37 2023-09-27 -0.310575 -2.079242	0.226382 0.959896 457.082478 False Normal Highly Predictable	0
38 2023-10-25 -0.347659 -1.999337	0.261049 0.942420 457.082478 False Normal Highly Predictable	0
39 2023-11-22 -0.420165 -2.013467	0.302959 0.819558 457.082478 False Normal Highly Predictable	0
40 2023-12-21 -0.457298 -2.059835	0.353011 0.748656 457.082478 True Anomalous Highly Predictab	
41 2024-01-23 -0.405623 -2.207048	0.414193 0.733788 457.082478 False Normal Highly Predictable	0
42 2024-02-21 -0.248144 -2.028939	0.339522 0.780970 457.082478 False Normal Highly Predictable	0
43 2024-03-20 -0.132551 -1.558388	0.240259 0.799397 457.082478 False Normal Highly Predictable	0
44 2024-04-18 -0.053887 -1.434960	0.205091 0.804113 457.082478 False Normal Highly Predictable	0
45 2024-05-16 0.094609 -1.595905	0.237021 0.791629 457.082478 False Normal Highly Unstable	0
46 2024-05-14 0.315525 -1.691326	0.193055 0.858122 457.082478 False Normal Highly Unstable	0
47 2024-07-16 0.512795 -1.828683	0.195648 0.956868 457.082478 False Normal Highly Unstable	0
48 2024-08-13 0.667430 -2.092527	0.272431 0.972230 457.082478 False Normal Highly Unstable	0
49 2024-09-11 0.731216 -2.273755	0.349229 0.898762 457.082478 True Anomalous Highly Unstable	e 1
50 2024-10-09 0.811011 -2.437546	0.426100 0.812334 457.082478 False Normal Highly Unstable	0
51 2024-11-05 0.852775 -2.583954	0.537027 0.735074 457.082478 False Normal Highly Unstable	0
52 2024-12-05 0.823278-2.671116	0.589112 0.704049 457.082478 False Normal Highly Unstable	0
53 2025-01-05 0.820588 -2.853389	0.656433 0.662118 457.082478 True Anomalous Highly Unstable	e 1
54 2025-02-05 0.859735 -3.165928	0.711092 0.630540 457.082478 False Normal Highly Unstable	0
55 2025-03-05 0.752239 -3.718308	0.924913 0.426672 457.082478 False Normal Highly Unstable	0
56 2025-04-03 0.716767 -3.831596	0.914636 0.404473 457.082478 False Normal Highly Unstable	0

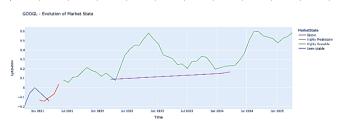


Figure 17. Evaluation of Market State

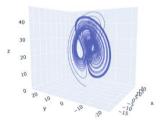
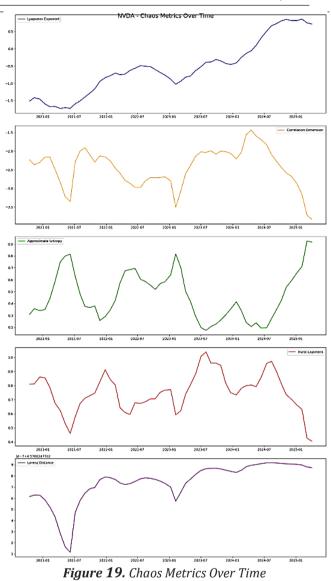


Figure 18. Lorenz Attractor Reference



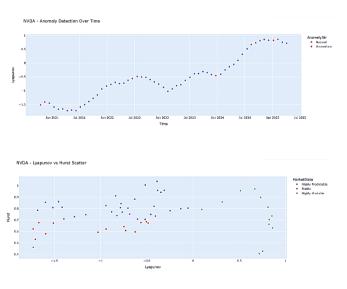


Figure 20. Lyapunov vs Hurst Scatter and Anomaly Detection over Time for Nvidia Inc.

The following images show the results for Intel. (Figure 21, Figure 22, Figure 23, Figure 24 and Figure 25).

Time Lyapunov CorrDin Approxit	ntropy Burst LorenzDist Anomaly AnomalyStr NarketState AnomalySum	
0 2020-10-15 -0.424003 -2.617638	0.615295 0.461965 457.082478 False Normal Highly Unstable	0
1 2020-11-13 -0.365253 -2.736064	0.603725 0.433928 457.082478 False Normal Highly Unstable	0
2 2020-12-14 -0.463912 -2.774591	0.586408 0.421324 457.082478 False Normal Highly Unstable	0
3 2021-01-13 -0.594427 -2.634219	0.593924 0.531664 457.082478 False Normal Stable 0	+
4 2021-02-11 -0.564841 -2.619010	0.543420 0.527267 457.082478 False Normal Stable 0	+
5 2021-03-12 -0.527621 -2.586607	0.549392 0.524231 457.082478 True Anomalous Stable 1	-
6 2021-04-12 -0.416762 -2.516707	0.482089 0.569540 457.082478 False Normal Stable 0	+
7 2021-05-10 -0.398117 -2.498904	0.485705 0.573017 457.082478 False Normal Stable 0	-
8 2021-05-08 -0.405052 -2.683480	0.513295 0.586593 457.082478 False Normal Stable 0	+
9 2021-07-07-0.408022-2.665350	0.532976 0.606203 457.082478 False Normal Stable 0	+
10 2021-08-04 -0.442134 -2.571445	0.551102 0.617262 457.082478 False Normal Stable 0	+
11 2021-09-01 -0.520105 -2.708675	0.566299 0.647833 457.082478 False Normal Stable 0	+
12 2021-09-30 -0.616904 -2.723037	0.632205 0.630392 457.082478 False Normal Stable 0	+
13 2021-10-28 -0.765735 -2.691562	0.652661 0.543662 457.082478 False Normal Stable 0	+
14 2021-11-26 -0.751226 -2.534832	0.562709 0.599812 457.082478 True Anomalous Stable 1	+
15 2021-12-27 -0.837840 -2.468935	0.585456 0.661675 457.082478 False Normal Stable 0	+
16 2022-01-25 -0.964396 -2.917383	0.750904 0.592954 457.082478 False Normal Stable 0	+
17 2022-02-23 -0.999443 -3.207071	0.789703 0.438736 457.082478 False Normal Highly Unstable	0
18 2022-03-23 -0.931909 -3.070995	0.795941 0.434188 457.082478 False Normal Highly Unstable	ŏ
19 2022-04-21 -0.940983 -3.170581	0.811345 0.437230 457.082478 False Normal Highly Unstable	0
20 2022-04-21 -0.940985 -5.170581	0.764032 0.457901 457.082478 True Anomalous Highly Unstable	- ·
21 2022-05-17 -0.692758 -3.140180	0.752035 0.522622 457.082478 False Normal Stable 0	-
22 2022-07-19 -0.643413 -2.857779	0.752055 0.522622 457.082478 False Normal Stable 0	+
		+
23 2022-08-16 -0.565535 -2.794834		_
24 2022-09-14 -0.446042 -2.654628		0
25 2022-10-12 -0.387693 -2.470117	0.427490 0.831444 457.082478 False Normal Highly Predictable	0
26 2022-11-09 -0.444529 -2.355722	0.407808 0.819190 457.082478 False Normal Highly Predictable	0
27 2022-12-08 -0.428713 -2.419400	0.374112 0.803202 457.082478 False Normal Highly Predictable	0
28 2023-01-09 -0.469132 -2.305339	0.347555 0.796780 457.082478 False Normal Highly Predictable	0
29 2023-02-07 -0.602910 -2.338471	0.471399 0.721487 457.082478 False Normal Highly Predictable	0
30 2023-03-08 -0.730077 -2.380276	0.498318 0.699116 457.082478 False Normal Stable 0	_
31 2023-04-05 -0.845793 -2.656051	0.639010 0.617885 457.082478 False Normal Stable 0	_
32 2023-05-04 -0.895849 -2.910013	0.682810 0.574831 457.082478 False Normal Stable 0	
33 2023-05-02 -1.016584 -3.509061	0.845107 0.461520 457.082478 False Normal Highly Unstable	0
34 2023-07-03 -0.961298 -3.455390	0.794541 0.433807 457.082478 False Normal Highly Unstable	0
35 2023-08-01 -0.903950 -3.295162	0.768781 0.454380 457.082478 False Normal Highly Unstable	0
36 2023-08-29 -0.878629 -3.297513	0.769799 0.509466 457.082478 False Normal Stable 0	
37 2023-09-27 -0.777034 -3.135569	0.713737 0.535082 457.082478 False Normal Stable 0	
38 2023-10-25 -0.784289 -3.194793	0.722738 0.528052 457.082478 False Normal Stable 0	
39 2023-11-22 -0.687330 -3.036034	0.665085 0.608918 457.082478 False Normal Stable 0	
40 2023-12-21 -0.653755 -2.729146	0.546010 0.601356 457.082478 False Normal Stable 0	Т
41 2024-01-23 -0.577596 -2.445590	0.482891 0.656050 457.082478 False Normal Stable 0	Т
42 2024-02-21 -0.529785 -2.458362	0.506553 0.704824 457.082478 False Normal Highly Predictable	0
43 2024-03-20 -0.595460 -2.503784	0.522454 0.616056 457.082478 False Normal Stable 0	T
44 2024-04-18 -0.592923 -2.623135	0.545294 0.584867 457.082478 False Normal Stable 0	T
45 2024-05-16 -0.556113 -2.593941	0.488096 0.593260 457.082478 False Normal Stable 0	+
45 2024-05-14 -0.601854 -2.489216	0.476642 0.626265 457.082478 False Normal Stable 0	\top
47 2024-07-16 -0.653104 -2.246914	0.432172 0.679632 457.082478 False Normal Stable 0	+
48 2024-08-13 -0.561591 -2.050520	0.385987 0.791299 457.082478 False Normal Highly Predictable	0
49 2024-09-11-0.584276 -1.879771	0.280834 0.865620 457.082478 False Normal Highly Predictable	0
50 2024-10-09 -0.563648 -1.929471	0.244977 0.880438 457.082478 False Normal Highly Predictable	ō
51 2024-11-05 -0.682677 -1.867723	0.228437 0.853912 457.082478 False Normal Highly Predictable	ŏ
52 2024-12-05 -0.653207 -1.998599	0.283282 0.807598 457.082478 False Normal Highly Predictable	ŏ
53 2025-01-06 -0.727740 -1.958399	0.294853 0.788419 457.082478 False Normal Highly Predictable	0
54 2025-02-05 -0.947497 -1.985769	0.392914 0.605145 457.082478 False Normal Stable 0	Ť
55 2025-03-05 -0.896578 -2.165653	0.392914 0.000146 457.082478 False Normal Stable 0	+
55 2025-05-06-0.896578-2.165655 56 2025-04-03-0.901776-2.341066	0.555140 0.531655 457.082478 False Normal Stable 0	+
302023-04-05-0.901770-2.341055	0.333140 0.331035 457.062476 Faise Normal Stable 0	_

Figure 21. Summary of Quantitative Data for Intel Inc.

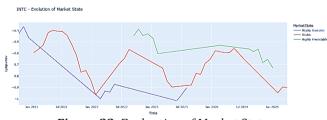


Figure 22. Evaluation of Market State

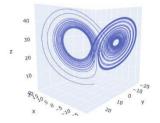


Figure 23. Lorenz Attractor Reference

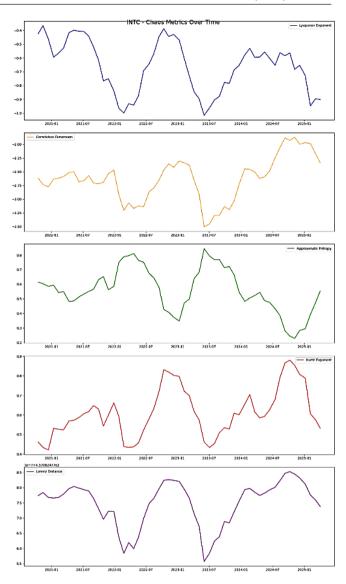


Figure 24. Chaos Metrics Over Time

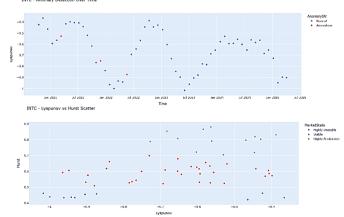


Figure 25. Lyapunov vs Hurst Scatter and Anomaly Detection over Time for Intel Inc.

The following images show the results for AMD (Figure 26, Figure 27, Figure 28, Figure 29 and Figure 30).

2021-05-08-0.002978-3.820128 0.972819 0.378845 457.082478 False Normal Highly Unstable 2021-07-07 0.010259-3.699940 0.934923 0.402972 457.082478 False Normal Highly Unstable	0 0 0
2020-11-13 0.218656-1.988687 0.449416 0.724521 457.082478 False Normal Highly Unstable 2020-11-13 0.2138142 0.359342 0.735767 457.082478 False Normal Highly Unstable 2020-11-13 0.158047-1.9134942 0.378247 0.775104 57.082478 False Normal Highly Unstable 2021-01-13 0.159369-2.04274 0.443036 0.711267 457.082478 False Normal Highly Unstable 2021-04-12 0.193969-2.032787 0.543326 0.697491 457.082478 False Normal Highly Unstable 2021-05-10 0.040092-3.712148 0.994198 0.556160 457.082478 False Normal Highly Unstable 2021-05-06 0.002678-3.820128 0.972453 0.594184 57.082478 False Normal Highly Unstable 2021-05-06 0.036261 0.772189 0.54212 0.500944 7.082478 False Normal Highly Unstable 2021-05-08 0.525213 0.770591 0.5	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
2020-12-14 0.243738-1.549642 0.398342 0.75767 457.082478 False Normal Highly Unstable 2021-02-11 0.18369504274 0.443036 0.711257 457.082478 False Normal Highly Unstable 2021-02-11 0.15369504274 0.443036 0.711257 457.082478 False Normal Highly Unstable 2021-02-11 0.193895232787 0.543326 0.697491 457.082478 False Normal Highly Unstable 2021-04-10 0.010319727451 0.6994198 0.566160 457.082478 False Normal Stable 2021-05-00 0.01229-3.029074 0.3934198 0.566160 457.082478 False Normal Highly Unstable 2021-05-00 0.01229-3.029074 0.393129 0.39323 0.40272478 False Normal Highly Unstable 2021-05-00 0.0255213-2.770591 0.642122 0.530684 7.082478 False Normal Highly Unstable 2021-10-26 0.3356774-2.570138 0.54785 0.542135	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
2021-01-13 0.180407-1.913419 0.378247 0.779190 457.082478 False Normal Highy Unstable 2021-02-11 0.153869-2.042724 0.443036 0.711267 457.082478 Title Normal Highy Unstable 2021-03-12 0.191890-2.33256 0.597413 457.082478 False Normal Highy Unstable 2021-03-12 0.191890-2.33256 0.596143 457.082478 False Normal Highy Unstable 2021-05-06 0.000273-3.12148 0.994138 0.556160 457.082478 False Normal Highy Unstable 2021-05-06 0.002325-3.420500 0.911282 0.5172189 0.782474 False Normal Highy Unstable 2021-05-06 0.083256-3.420500 0.911282 0.5172189 Normal Highy Unstable 2021-05-06 0.083256-3.427518 0.42122 0.560091 K57.082478 False Normal Highy Unstable 2021-05-06 0.315620 0.517285 0.624127 K7.082478 False Normal Highy Unstable 2021-05-26 0.5261520 0.34646 6.79325 457.082478	0 0 0 0 0 0 0 0 0 0 0 0 0 0
2021-02-11 0.153969-2.042724 0.443036 0.711267 457.082478 True Anomalous Highly Unstable 2021-03-12 0.19180-2.332787 0.543326 0.674914 457.082478 False Normal Highly Unstable 2021-04-12 0.19180-2.332787 0.543326 0.674914 457.082478 False Normal Highly Unstable 2021-04-12 0.19318-2.72451 0.699741 657.082478 False Normal Highly Unstable 2021-05-07 0.040092-3.712148 0.994158 0.556160 457.082478 False Normal Highly Unstable 2021-05-07 0.010259-3.699940 0.934923 0.402972 457.082478 False Normal Highly Unstable 2021-07-07 0.010259-3.699940 0.934923 0.402972 457.082478 False Normal Highly Unstable 2021-07-07 0.010259-3.699940 0.934923 0.402972 457.082478 False Normal Highly Unstable 2021-07-08 0.0157064 - 2005070 0.731593 0.559684 857.082478 False Normal Highly Unstable 2021-10-28 0.333767 - 2.570158 0.544785 0.628131 457.082478 False Normal Highly Unstable 2021-10-28 0.584541 - 2.692595 0.74052 0.739579 457.082478 False Normal Highly Unstable 2022-02-23 0.856774 - 2.515469 0.493160 0.739579 457.082478 False Normal Highly U	e 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
2021-03-12 0.191580-2.332767 0.54332 0.697491 457.082478 False Normal Highly Unstable 2021-03-10 0.60092-3.712148 0.696761 0.690294 457.082478 False Normal Highly Unstable 2021-05-10 0.60092-3.712148 0.991398 0.556160 457.082478 False Normal Highly Unstable 2021-05-10 0.00259-3.5802128 0.972819 0.738454 457.082478 False Normal Highly Unstable 2021-07-07 0.00259-3.690214 0.931232 0.40272 457.082478 False Normal Highly Unstable 0.201-07-07 0.01252 0.550588 457.082478 False Normal Highly Unstable 0.201-09-00 0.052513 - 2.770591 0.544725 0.624127 0.63014 457.082478 False Normal Highly Unstable 2.021-09-30 0.252133 - 2.770591 0.544725 0.624135 0.624278 False Normal Highly Unstable 2.021-02-30 0.521893 - 1.942189 0.340640 0.793254 7.082478 False Normal Highly Unstable 2.022-04-12	0 0 0 0 0 0 0 0 0 0
2021-04-12 0.190319-2.724561 0.696761 0.690294 457.082478 False Normal Highly Unstable 2021-05-10 0.040092-3.712148 0.994198 0.556160 457.082478 False Normal Stable 2021-05-08 0.002973 3.82019 0.378424 57.082478 False Normal Stable 2021-06-08 0.002973 3.62019 0.378424 57.082478 False Normal Highly Unstable 2021-06-00 0.0255213 2.770591 0.542122 0.530091 457.082478 False Normal Highly Unstable 2021-10-50 0.255213 2.770591 0.542122 0.530091 457.082478 False Normal Highly Unstable 2021-10-26 0.5258193 1.942580 0.340646 6.79325 457.082478 False Normal Highly Unstable 2022-01-25 0.556174 5.75082478 False Normal Highly Unstable 2022-02-21 0.654152 0.730425 0.6264217 F7082478 Fal	0 0 0 0 0 0 0 0 0
2021-05-10 0.040092-3.712148 0.994158 0.556150 457.082478 False Normal Stable 2021-05-07 0.00259-3.820128 0.972819 0.378845 457.082478 False Normal Highly Unstable 2021-07-07 0.00259-3.699940 0.934923 0.402972 457.082478 False Normal Highly Unstable 0.201-07-07 0.010259-3.699940 0.931282 0.516723 457.082478 False Normal Stable 1.021-09-01 0.197064 2.0201-07-07 0.702319 0.559636 S7.082478 False Normal Semi-Stable 2.021-09-30 0.265213-2.770591 0.642122 0.630091 457.082478 False Normal Highly Unstable 2.021-10-26 0.335707-2.570138 0.54475 0.628137 False Normal Highly Unstable 2.022-04-21 0.642122 0.330609 0.739379 457.082478 False Normal Highly Unstable 2.022-04-21 0.654125 0.7412550 0.336292 0.730423	0 0 0 0 0 0 0 0
2021-06-08-0.002978-3.820128 0.972819 0.378845 457.082478 False Normal Highly Unstable 2021-07-07 0.003236-3.409940 0.93423 0.402972 457.082478 False Normal Highly Unstable 2021-08-00.003236-3.409940 0.93423 0.402972 457.082478 False Normal Highly Unstable 2021-08-00 0.93236-3.409940 0.723193 0.559658 457.082478 False Normal Highly Unstable 2021-09-01 0.197064-2.902697 0.723193 0.559658 457.082478 False Normal Highly Unstable 2021-10-26 0.333767 -2.570138 0.544785 0.628113 457.082478 False Normal Highly Unstable 2021-12-26 0.531633 1.942580 0.336109 0.803188 457.082478 False Normal Highly Unstable 2022-12-27 0.644571 -1.925690 0.336109 0.803188 457.082478 False Normal Highly Unstable 2022-04-21 0.854514 0.5708450 0.793845 457.082478 False Normal Highly Unstable	0 0 0 0 0
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0 2021-08-04 0.083236-3.450550 0.911282 0.516723 457.082478 False Normal Stable 1 2021-09-01 0.197064-2.902697 0.723139 0.559688 457.082478 False Normal Semi-Stable 1 2021-09-01 0.25213-2.770591 0.642122 0.630091 457.082478 False Normal Semi-Stable 3 2021-10-28 0.25213-2.770591 0.544725 0.628131 457.082478 False Normal Highly Unstable 3 2021-10-28 0.5315677-2.570138 0.544785 0.628131 457.082478 False Normal Highly Unstable 5 2021-10-28 0.521593 -1.94298 0.340646 0.679325 457.082478 False Normal Highly Unstable 5 2022-01-25 0.7665074 -5.15469 0.493158 0.735974 457.082478 False Normal Highly Unstable 7 2022-02-28 0.585774 -5.15459 0.493158 0.735794 457.082478 False Normal Highly Unstable 7 2022-02-28 0.585774 -5.15459 0.624405 0.665217 457.082478 False Normal Highly Unstable 7 2022-02-28 0.58431 -2.693250 0.71425 0.625634 457.082478 False Normal Highly Unstable 7 2022-07-19 0.917769 -2.89156 0.78124 0.600836 457.082478 False	0 0 0 0
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3 2021-10-28 0.333767-2.570138 0.544785 0.628131 457.082478 False Normal Highly Unstable 4 2021-11-26 0.521893 -1.942989 0.34064 0.679325 457.082478 False Normal Highly Unstable 5 2021-12-27 0.644571 - 1.92591 0.3368629 0.793845 457.082478 False Normal Highly Unstable 6 2022-01-25 0.645671 - 2.51869 0.386829 0.793845 457.082478 False Normal Highly Unstable 7 2022-02-23 0.856774 - 2.518459 0.628105 0.668611 47.082478 False Normal Highly Unstable 7 2022-02-23 0.8545714 - 2.695257 0.624405 0.668211 47.082478 False Normal Highly Unstable 7 2022-02-31 0.854431 - 2.695257 0.714236 0.626454 457.082478 False Normal Highly Unstable 7 2022-02-19 0.917769 - 2.839156 0.731082 0.570943 457.082478 False Normal Highly Unstable 7 2022-07-19 0.945851 - 2.95158 0.67814 0.698456 457.082478 False Normal Highly Unstable 7 2022-07-19 1.077469 - 3.054069 0.676949 0.635697 457.082478 False Normal Highly Unstable 7 2022-07-19 1.077469 - 3.052405 0.656058 0.6829288 457.082478 False Normal Highly Unstable 7 2022-07-19 1.077469 - 3.052405 0.6560284 0.6758477 67	0
4 2021-11-26 0.521893 -1.942989 0.340646 0.679325 457.082478 False Normal Highly Unstable 5 2021-12-27 0.644571 -1.925691 0.336109 0.803188 457.082478 False Normal Highly Unstable 5 2021-01-25 0.556190 - 1.856794 2.515280 0.738162 0.738162 Normal Highly Unstable 7 2022-02-23 0.556774 -2.515469 0.493159 0.739579 457.082478 False Normal Highly Unstable 8 2022-03-23 0.584215 - 2.695255 0.714236 0.6264217 F7.082478 False Normal Highly Unstable 9 2022-04-21 0.634215 - 0.626434 457.082478 False Normal Highly Unstable 9 2022-04-21 0.84215 - 2.695255 0.714236 0.626436 457.082478 False Normal Highly Unstable 9 2022-07-19 1.077480 - 3.052405 0.676818 0.595455 457.082478 False Normal Highly Unstable 2 2022-07-19 1.077480 - 3.052405 0.676812 0.6768527 6.7082478 False Normal Highly Unstable 2 2022-07-19 1.077480 - 3.	0
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7 2022-02-23 0.856774 - 2.515469 0.493196 0.739579 457.082478 True Anomalous Highly Unstable 8 2022-02-23 0.854431 - 2.695257 0.624405 0.666217 457.082478 False Normal Highly Unstable 9 2022-04-21 0.854131 - 2.695257 0.74125 0.624435 0.86217 457.082478 False Normal Highly Unstable 0 2022-05-19 0.854152 0.731082 0.570943 457.082478 False Normal Highly Unstable 0 2022-05-19 0.848981 - 2.695868 0.7662340 600863 457.082478 False Normal Highly Unstable 2 2022-07-19 1.077480-3.062406 0.676818 0.595465 457.082478 False Normal Highly Unstable 2 2022-07-19 1.077480-3.062406 0.676818 0.595455 457.082478 False Normal Highly Unstable 2 2022-07-19 1.077480-3.062405 0.6560280 0.6729286 457.082478 False Normal Highly Unstable 2 2022-07-10-12 0.976886-2.983130 0.6560284 0.6768497 457.082478 False Normal Highly Unstable <td>0</td>	0
8 2022-03-23 0.884431 - 2.695257 0.624405 0.666217 457.082478 False Normal Highy Unstable 9 2022-04-21 0.864215 - 2.605257 0.714236 0.626454 457.082478 False Normal Highy Unstable 0 2022-0519 0.917769 - 2.85156 0.731028 0.5706434 87.082478 False Normal Highy Unstable 1 2022-05-17 0.945881 - 2.959883 0.768234 0.600836 457.082478 False Normal Highy Unstable 2 0022-0519 0.858351 - 0.305406 0.678418 0.595455 457.082478 False Normal Highy Unstable 2 0022-0514 1.0274650 - 3.052406 0.678418 0.595465 457.082478 False Normal Highy Unstable 2 0022-0514 1.024652 - 2.953152 0.648532 0.652852 457.082478 False Normal Highy Unstable 2 022-071-01 2.0.9768865 - 2.983310 0.6550588 0.629288 457.082478 False Normal Highy Unstable 2 022-10-12 0. 0.784055 - 2.981350 0.650249 0.678497 457.082478 False Normal Highy Unstable 2 022-11-10 0.8.03985 - 2.981350 0.650256 0.6650257 457.082478 False Normal Highy Unstable 2 022-11-10 0.78405 - 2.981350 0.650256 0.6650547 457.082478 False Normal Highy Unstable 2 022-11-10 0.78405 - 2.981350 0.650256 0.6650547 457.082	le 1
9 2022-04-21 0.864215-2.805525 0.714236 0.626454 457.082478 False Normal Highly Unstable 0 2022-05-19 0.917769-2.839156 0.731082 0.570943 457.082478 False Normal Highly Unstable 1 2022-05-17 0.948581 -358885 0.768243 0.600354 87.082478 False Normal Highly Unstable 2 2022-07-19 1.077469-0.3052406 0.678418 0.595455 457.082478 False Normal Highly Unstable 2 2022-06-16 1.088351 -3.034993 0.676946 0.636597 457.082478 False Normal Highly Unstable 2 2022-06-16 1.024562 -2.953152 0.645852 0.652247.082478 False Normal Highly Unstable 2 2022-01-12 0.976886-2.983130 0.6550254 0.6502478 False Normal Highly Unstable 2 2022-10-12 0.976886-2.983130 0.6550254 0.6502478 False Normal Highly Unstable 2 2022-11-90 0.870985-2.981336 0.6550256 0.650257 7.082478 False Normal Highly Unstable 2	0
0 2022-05-19 0.917769 -2.839156 0.731082 0.570643 457.082478 False Normal Highly Unstable 1 2022-05-17 0.945881 -2.959883 0.768234 0.600836 457.082478 False Normal Highly Unstable 2 2022-07-19 1.077480 -3.052405 0.778418 0.598455 457.082478 False Normal Highly Unstable 3 2 2022-08-15 1.088351 -3.034993 0.676959 0.6356597 457.082478 False Normal Highly Unstable 2 2 2 2 - 08-15 1.02652 - 2.95312 0.645852 0.652652 457.082478 False Normal Highly Unstable 5 2 0 - 0.976866 -2.983310 0.656688 0.69298 457.082478 False Normal Highly Unstable 6 2 0 - 0.976846 -2.983310 0.656688 0.69298 457.082478 False Normal Highly Unstable 6 2 0 - 0.9768405 -2.983310 0.655052 0.656567 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.655057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.655057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.655057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.655057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.655057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.655057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.655057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.655057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.655057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.655057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False Normal Highly Unstable 7 0 - 0.550 0.55057 457.082478 False N	0
1 2022-05-17 0.948981-2.959883 0.768234 0.600836 457.082478 False Normal Highy Unstable 2 2022-07-19 1.077480-3.052406 0.678418 0.598455 457.082478 False Normal Highy Unstable 3 2022-05-16 1.088351-3.032406 0.678959 0.635959 0.63597 False Normal Highy Unstable 4 2022-09-14 1.024662-2.953152 0.648532 0.652858 457.082478 False Normal Highy Unstable 5 2022-10-12 0.9768865-2.983310 0.6550288 0.650248 457.082478 False Normal Highy Unstable 6 2022-11-90 0.830985-2.981316 0.650249 0.675042747 False Normal Highy Unstable 7 2022-12-08 0.784052-2.981326 0.650254 0.676827478 False Normal Highy Unstable	ő
2 2022-07-19 1.077480-3.052405 0.678418 0.595455 457.082478 False Normal Highly Unstable 3 2022-06-16 1.088351-3.03499 0.676959 0.636597 457.082478 False Normal Highly Unstable 3 2022-06-14 1.024562 .055125 0.645825 0.652325 0.652525 0.55252 0.55252 0.550254 Normal Highly Unstable 5 2022-10-12 0.9768865-2.983310 0.6550284 0.6702988 437.082478 False Normal Highly Unstable 6 2022-11-09 0.870895-2.981336 0.6550254 0.656287 457.082478 False Normal Highly Unstable 7 2022-12-08 0.781405-2.981352 0.6550256 0.656257 457.082478 False Normal Highly Unstable	ŏ
3 2022-08-16 1.088351-3.034993 0.676996 0.636597 457.082478 False Normal Highly Unstable 4 2022-09-14 1.024652-2.953152 0.648532 0.652852 457.082478 False Normal Highly Unstable 5 2022-10-12 0.976886-2.983310 0.656688 0.692988 457.082478 False Normal Highly Unstable 5 2022-10-12 0.976886-2.983310 0.650294 0.6784974 False Normal Highly Unstable 5 2022-11-20 0.830895-2.98310 0.650294 0.6784974 False Normal Highly Unstable 7 2022-12-08 0.781405-2.970552 0.650256 0.666867 457.082478 False Normal Highly Unstable	ō
4 2022-09-14 1.024662-2.953152 0.648532 0.652852 457.082478 False Normal Highly Unstable 5 2022-10-12 0.976886-2.983310 0.655688 0.692988 457.082478 False Normal Highly Unstable 6 2022-11-09 0.830985-2.983310 0.656028 0.678497 457.082478 False Normal Highly Unstable 7 2022-12-08 0.781405-2.970552 0.650254 0.678247 False Normal Highly Unstable	0
5 2022-10-12 0.976886-2.683310 0.656688 0.682988 457.082478 False Normal Highly Unstable 6 2022-11-09 0.830985-2.981336 0.650294 0.678497 457.082478 False Normal Highly Unstable 7 2022-12-08 0.781405-2.97525 0.650256 0.655025 0.65025 6.65667 False Normal Highly Unstable	0
6 2022-11-09 0.830985 -2.981336 0.650294 0.678497 457.082478 False Normal Highly Unstable 7 2022-12-08 0.781405 -2.970552 0.650256 0.666867 457.082478 False Normal Highly Unstable	
7 2022-12-08 0.781405 -2.970552 0.650256 0.666867 457.082478 False Normal Highly Unstable	0
• •	0
8 2023-01-09 0.694005 -2.958918 0.645611 0.662498 457.082478 False Normal Highly Unstable	0
	0
9 2023-02-07 0.592481-3.084017 0.739124 0.577614 457.082478 False Normal Highly Unstable	0
0 2023-03-08 0.534046 -3.044397 0.677939 0.602255 457.082478 False Normal Highly Unstable	0
1 2023-04-05 0.458397 -3.026707 0.660494 0.625490 457.082478 False Normal Highly Unstable	0
2 2023-05-04 0.465214 -3.051774 0.655494 0.620785 457.082478 False Normal Highly Unstable	0
3 2023-06-02 0.545820 -2.827256 0.574684 0.672328 457.082478 False Normal Highly Unstable	0
4 2023-07-03 0.622019 - 2.564275 0.477691 0.726218 457.082478 False Normal Highly Unstable	0
5 2023-08-01 0.665257 -2.608092 0.435005 0.762348 457.082478 False Normal Highly Unstable	0
6 2023-08-29 0.668733 -2.687145 0.489260 0.731364 457.082478 False Normal Highly Unstable	0
7 2023-09-27 0.646609 -2.775393 0.525743 0.743210 457.082478 False Normal Highly Unstable	0
8 2023-10-25 0.602788 -2.958918 0.616665 0.695722 457.082478 False Normal Highly Unstable	0
9 2023-11-22 0.518003 -3.135569 0.692610 0.620610 457.082478 False Normal Highly Unstable	0
0 2023-12-21 0.544615 -3.113953 0.704346 0.560107 457.082478 False Normal Highly Unstable	0
1 2024-01-23 0.684008 - 2.701944 0.569824 0.713655 457.082478 False Normal Highly Unstable	0
2 2024-02-21 0.738776 -2.242667 0.436919 0.726443 457.082478 False Normal Highly Unstable	0
3 2024-03-20 0.901121-1.946485 0.364200 0.804022 457.082478 False Normal Highly Unstable	0
4 2024-04-18 0.928864 -2.033513 0.375662 0.808096 457.082478 False Normal Highly Unstable	0
5 2024-05-15 1.014580 -2.282047 0.402971 0.780488 457.082478 False Normal Highly Unstable	0
5 2024-05-14 1.029294 -2.474857 0.455833 0.805465 457.082478 False Normal Highly Unstable	ŏ
7 2024-07-15 1.059269-2.627969 0.505484 0.830205 457.082478 False Normal Highly Unstable	ō
2024-07-10 1.039269-2.027969 0.305464 0.830206 437.082478 Palse Normal Highly Unstable 8 2024-08-13 1.075720-2.904521 0.602173 0.810093 457.082478 False Normal Highly Unstable	0
9 2024-09-11 1.008192 -3.177854 0.712621 0.645059 457.082478 False Normal Highly Unstable	0
	0
1 2024-11-05 0.937043 -3.374799 0.842884 0.540013 457.082478 True Anomalous Highly Unstab	
2 2024-12-05 0.928364 -3.194793 0.780557 0.549776 457.082478 False Normal Highly Unstable	0
3 2025-01-05 0.848236 -3.401447 0.806329 0.500364 457.082478 False Normal Highly Unstable	0
4 2025-02-05 0.888949 -3.248691 0.771911 0.559418 457.082478 False Normal Highly Unstable	
5 2025-03-05 0.980338 -2.968604 0.672513 0.646788 457.082478 False Normal Highly Unstable	0
6 2025-04-03 1.013504 -2.900877 0.592331 0.666291 457.082478 False Normal Highly Unstable	0

Figure 26. Summary of Quantitative Data for AMD Inc.

AMD - Evolution of Market State

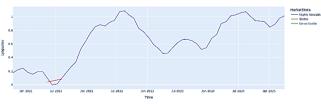


Figure 27. Evaluation of Market State

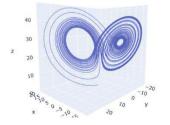


Figure 28. Lorenz Attractor Reference

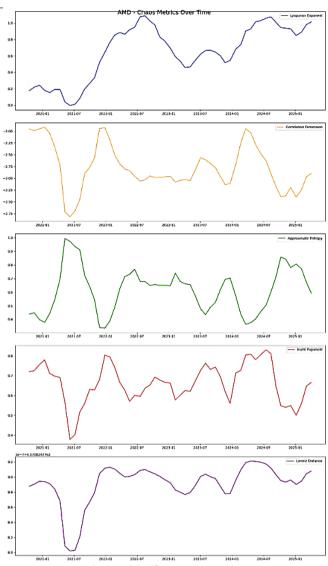
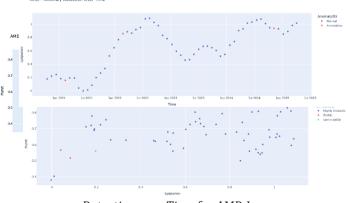


Figure 29. Chaos Metrics Over Time

Figure 30. Lyapunov vs Hurst Scatter and Anomaly

AMD - Anomaly Detection Over Time



Detection over Time for AMD Inc.

The following images show the results for IBM. (Figure 31, Figure 32, Figure 33, Figure 34 and Figure 35).

2020-10-16 0.153679 -2.700454	0.597262 0.571805		False	Normal	Semi-Stable	0
2020-11-13 0.128770 -2.658189	0.631512 0.563277		False	Normal	Semi-Stable	0
2020-12-14 -0.041398 -3.239716	0.791168 0.455410		False	Normal	Highly Unstable	0
2021-01-13 -0.225441 -3.656412	0.903128 0.440570		False	Normal	Highly Unstable	0
2021-02-11 -0.316814 -3.843197	0.915222 0.421014		False	Normal	Highly Unstable	0
2021-03-12 -0.363144 -3.683892	0.921194 0.432346		False	Normal	Highly Unstable	0
2021-04-12 -0.298085 -3.191139	0.807095 0.488751		False	Normal	Highly Unstable	0
2021-05-10 -0.178567 -2.631436	0.622739 0.614146		False	Normal		0
2021-05-08 -0.097929 -2.470117	0.551449 0.642535		False	Normal		0
2021-07-07-0.003700-2.387871	0.485524 0.662577		False	Normal		0
0 2021-08-04 0.001020 -2.405558	0.451725 0.704835		False		Highly Predictable	
1 2021-09-01 -0.181811 -2.314405	0.470522 0.627051			Normal		0
2 2021-09-30 -0.194880 -2.405003	0.492800 0.626967			Normal	Stable	0
3 2021-10-28 -0.209556 -2.346276	0.513602 0.579794			Anomalou		1
4 2021-11-26 -0.271930 -2.482011	0.554112 0.573701	L 457.082478	False	Normal	Stable	0
5 2021-12-27 -0.344654 -2.844300	0.705953 0.495209	457.082478		Normal	Highly Unstable	0
6 2022-01-25 -0.383218 -2.807180	0.722781 0.449594			Normal	Highly Unstable	0
7 2022-02-23 -0.395285 -2.846881	0.749305 0.462505			Normal	Highly Unstable	0
8 2022-03-23 -0.337852 -3.095105	0.768597 0.442851	457.082478	False	Normal	Highly Unstable	0
9 2022-04-21 -0.430032 -3.077485	0.747925 0.410505	5 457.082478	False	Normal	Highly Unstable	0
0 2022-05-19 -0.293052 -3.147137	0.750554 0.392083			Normal	Highly Unstable	0
1 2022-05-17 -0.148570 -3.212024	0.734011 0.419143	457.082478	False	Normal	Highly Unstable	0
2 2022-07-19 -0.058802 -3.162377	0.732993 0.414197	457.082478		Normal	Highly Unstable	0
3 2022-08-16 -0.076023 -3.220753	0.744571 0.451343	457.082478	False	Normal	Highly Unstable	0
4 2022-09-14 -0.126585 -3.444365	0.820191 0.429584	457.082478	False	Normal	Highly Unstable	0
5 2022-10-12 -0.167279 -3.658350	0.880073 0.376636	5 457.082478	False	Normal	Highly Unstable	0
5 2022-11-09 -0.120741 -3.654187	0.877058 0.391443	457.082478	False	Normal	Highly Unstable	0
7 2022-12-08 -0.000904 -3.177854	0.735899 0.435350	457.082478	False	Normal	Highly Unstable	0
8 2023-01-09 0.054888 -3.180256	0.729158 0.474707	457.082478	False	Normal	Semi-Stable	0
9 2023-02-07 0.059818 -3.225775	0.714628 0.498568	457.082478	False	Normal	Semi-Stable	0
0 2023-03-08 0.011210 -3.084017	0.684154 0.543982	457.082478	False	Normal	Stable	0
1 2023-04-05 0.008494 -3.055618	0.654464 0.544064	457.082478	True	Anomalou	s Stable	1
2 2023-05-04 -0.054229 -2.885533	0.616764 0.576823	457.082478	False	Normal	Stable	0
3 2023-05-02 -0.045828 -2.899059	0.621956 0.563373	457.082478	False	Normal	Stable	0
4 2023-07-03 -0.037136 -2.961814	0.639722 0.541017	7 457.082478	False	Normal	Stable	0
5 2023-08-01 -0.114753 -3.013387	0.634249 0.559667	7 457.082478	False	Normal	Stable	0
6 2023-08-29 -0.193135 -2.825568	0.572542 0.499534	457.082478	False	Normal	Highly Unstable	0
7 2023-09-27 -0.117807 -2.732215	0.534254 0.563380	457.082478	False	Normal	Stable	0
8 2023-10-25 -0.139138 -2.685677	0.540017 0.591898	8 457.082478	False	Normal	Stable	0
9 2023-11-22 -0.055713 -2.533572	0.454027 0.603552	457.082478	False	Normal	Stable	0
0 2023-12-21 0.055764 -2.356250	0.320292 0.658896	457.082478	False	Normal	Stable	0
1 2024-01-23 0.094532 -2.321004	0.266765 0.747753	457.082478	False	Normal	Highly Unstable	0
2 2024-02-21 0.238865 -2.126743	0.209024 0.777955		False	Normal	Highly Unstable	0
		457.082478				
	0.205978 0.772725		False	Normal	Highly Unstable	0
3 2024-03-20 0.258761 -1.995652	0.205978 0.772725 0.209328 0.768171	457.082478			Highly Unstable Highly Unstable	0
3 2024-03-20 0.258761 -1.995652 4 2024-04-18 0.282725 -1.987957		457.082478 457.082478	False False	Normal Normal		
3 2024-03-20 0.258761 -1.995652 4 2024-04-18 0.282725 -1.987957 5 2024-05-16 0.286482 -2.092527	0.209328 0.768171	457.082478 457.082478 457.082478	False False False	Normal	Highly Unstable Highly Unstable	0
3 2024-03-20 0.258761 -1.995652 4 2024-04-18 0.282725 -1.987957 5 2024-05-16 0.286482 -2.092527 5 2024-05-14 0.342998 -2.310365	0.209328 0.768171 0.257830 0.721351 0.289057 0.705929	457.082478 457.082478 457.082478 457.082478	False False False False	Normal Normal Normal Normal	Highly Unstable Highly Unstable Highly Unstable	0
3 2024-03-20 0.258761 -1.995652 4 2024-04-18 0.282725 -1.987957 5 2024-05-16 0.286482 -2.092527 5 2024-05-14 0.342998 -2.310365 7 2024-07-16 0.405666 -2.440411	0.209328 0.768171 0.257830 0.721351 0.289057 0.706929 0.342588 0.714432	457.082478 457.082478 457.082478 457.082478 457.082478 457.082478	False False False	Normal Normal Normal Normal Normal	Highly Unstable Highly Unstable Highly Unstable Highly Unstable	000000000000000000000000000000000000000
3 2024-03-20 0.258761 -1.995652 4 2024-04-18 0.282725 -1.987957 5 2024-05-16 0.286482 -2.092527 6 2024-05-14 0.342998 -2.310365 7 2024-07-16 0.405666 -2.440411 8 2024-08-13 0.374435 -2.614218	0.209328 0.768171 0.257830 0.721351 0.289057 0.705929 0.342588 0.714432 0.432218 0.694211	457.082478 457.082478 457.082478 457.082478 457.082478 457.082478 457.082478	False False False False False False	Normal Normal Normal Normal Normal	Highly Unstable Highly Unstable Highly Unstable Highly Unstable Highly Unstable	0 0 0 0 0 0 0
3 2024-03-20 0.258761 -1.995652 4 2024-04-18 0.282725 -1.987957 5 2024-05-16 0.258428 -2.092527 6 2024-06-14 0.342998 -2.310365 7 2024-07-16 0.405656 -2.440411 8 2024-08-13 0.374435 -2.614218 9 2024-09-11 0.365230 -2.730679	0.209328 0.768171 0.257830 0.721351 0.289067 0.706929 0.342588 0.714432 0.432218 0.694211 0.510443 0.604165	457.082478 457.082478 457.082478 457.082478 457.082478 457.082478 457.082478 457.082478	False False False False False False False	Normal Normal Normal Normal Normal Normal	Highly Unstable Highly Unstable Highly Unstable Highly Unstable Highly Unstable Highly Unstable	0 0 0 0 0
3 2024-03-20 0.258761 -1.995652 4 2024-04-18 0.282725 -1.987957 5 2024-05-16 0.286482 -2.092527 5 2024-05-14 0.342998 -2.310365 7 2024-07-16 0.405666 -2.440411 8 2024-08-13 0.374435 -2.614218 9 2024-091 0.365230 -2.736679 0 2024-10-09 0.503669 -2.473077	0.209328 0.768171 0.257830 0.721351 0.289057 0.705929 0.342588 0.714432 0.432218 0.694211 0.510443 0.604155 0.403234 0.665040	457.082478 457.082478 457.082478 457.082478 457.082478 457.082478 457.082478 457.082478 457.082478	False False False False False False False	Normal Normal Normal Normal Normal Normal Normal	Highly Unstable Highly Unstable Highly Unstable Highly Unstable Highly Unstable Highly Unstable Highly Unstable	0 0 0 0 0 0
3 2024-03-20 0.258761-1.995652 4 2024-04-18 0.282725-1.867595 7 2024-05-16 0.258428-2.025227 5 2024-05-16 0.342988-2.310365 7 2024-07-16 0.405666-2.440411 8 2024-09-11 0.355230-2.730679 0 2024-10-09 0.503689-2.473077 0 2024-10-09 0.503689-2.473077	0.209328 0.768171 0.257830 0.721351 0.289057 0.706929 0.342588 0.714432 0.432218 0.694211 0.510443 0.604165 0.403234 0.665008 0.380164 0.653058	457.082478 457.082478 457.082478 457.082478 457.082478 457.082478 457.082478 457.082478 457.082478	False False False False False False False False	Normal Normal Normal Normal Normal Normal Normal Normal	Highly Unstable Highly Unstable Highly Unstable Highly Unstable Highly Unstable Highly Unstable Highly Unstable Highly Unstable	0 0 0 0 0 0
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Figure 31. Summary of Quantitative Data for IBM Inc



Figure 32. Evaluation of Market State

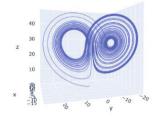
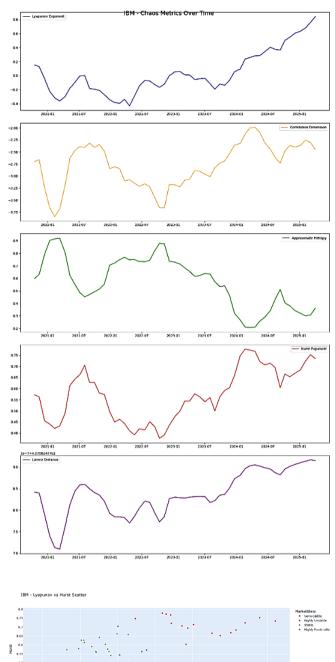


Figure 33. Lorenz Attractor Reference

Figure 34. Chaos Metrics Over Time



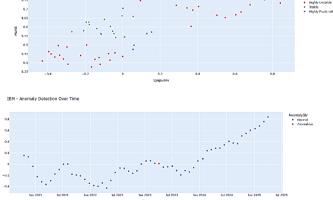


Figure 35. Lyapunov vs Hurst Scatter and Anomaly Detection over Time for IBM Inc

DISCUSSION

The combination of chaotic metrics (such as the Lyapunov exponent, correlation dimension, approximate entropy, Hurst exponent, and Lorenz distance) with an artificial immune system enables efficient market classification based on various dynamic states. This methodology not only uncovers the chaotic characteristics of the market but also allows for market classification by identifying stable and unstable patterns. In this work, the algorithms are applied in two modes: one without false alarms, and another where false alarms are introduced to test the system's robustness under conditions of high volatility. The discussion below thoroughly examines the classification results by company, clearly indicating the use of both algorithms. For a summarized overview of the key metrics for each company, please refer to **Table 2**. Time series analysis for Apple indicates the presence of chaotic yet predictable patterns in market behavior. The Lyapunov exponent, with values ranging between 0.48 and 0.56, confirms the system's divergence and the presence of chaos, which is characteristic of dynamic and nonlinear systems. However, the Approximate Entropy, ranging from 0.33 to 0.40, shows a relatively low level of entropy, suggesting that price movement patterns are somewhat predictable. A high Hurst exponent (~0.79-0.86) further suggests the existence of long-term dependence and stable trends—when the price rises, there is a high probability that the upward trend will persist. The correlation dimension, although negative (likely due to a scaling error), indicates a high level of complexity in market behavior. The Lorenz distance, with a constant value around 457, points to a stable attractor distribution, and the absence of anomalies confirms that the market chaos is unfolding within expected bounds. Time series analysis for Microsoft reveals more pronounced chaotic characteristics compared to Apple. The Lyapunov exponent ranges from 0.68 to 1.0, indicating a higher degree of chaos and greater system divergence. The correlation dimension, with values between -2.5 and -2.9, also suggests a high level of complexity, although the negative values are likely due to a scaling error. Approximate Entropy, in the range of 0.57 to 0.72, reflects greater unpredictability of patterns compared to Apple, meaning that Microsoft's market behavior is harder to model. The Hurst exponent remains relatively high (0.69–0.76),

confirming the presence of long-term dependencies, although somewhat less pronounced than in Apple's case. The Lorenz distance indicates lower attractor stability compared to Apple, further contributing to the depiction of a more dynamic and potentially more volatile market. Nevertheless, despite the stronger chaotic behavior, no anomalies were detected, indicating that Microsoft's market behavior-though complex and unpredictable-still occurs within expected bounds. Microsoft exhibits stronger chaotic characteristics and lower predictability compared to Apple, while maintaining fundamental structural stability. The Lyapunov exponent is negative (ranging from -0.18 to -0.00), indicating that the system is not divergent and does not exhibit chaotic characteristics-instead, the behavior is stable and predictable. The Hurst exponent, ranging from 0.5 to 0.6, suggests behavior close to a random walk, with no pronounced long-term dependence. Approximate Entropy falls within a moderate range (0.45–0.61), indicating a medium level of unpredictability-higher than Apple's, but lower than Microsoft's. The correlation dimension points to a complex structure, similar to the previous companies, suggesting multilayered dynamics despite the absence of chaos. The Lorenz distance remains stable, supporting the existence of a consistent attractor structure over time. No anomalies were recorded, further confirming the consistency of market behavior. Time series analysis for Google shows more stable dynamic behavior compared to Apple and Microsoft. In conclusion, Google stands out as a system with stable and relatively predictable patterns, lacking chaos and exhibiting less long-term dependence compared to Apple and Microsoft. The Lyapunov exponent for NVIDIA has extremely negative values (~-1.5 to -1.6), indicating an exceptionally stable system with no signs of divergence. The Hurst exponent ranges from 0.6 to 0.7, suggesting the presence of mild, mostly upward trends in the time series. Approximate Entropy, ranging from 0.30 to 0.44, indicates a relatively low level of unpredictability, meaning that behavioral patterns are clearly present and can be modeled with relative ease. NVIDIA demonstrates a high degree of stability with moderate trends and low entropy, making it a system with well-defined and predictable dynamics. The Lyapunov exponent for Intel ranges between -0.42 and -0.59, indicating stable system behavior

without signs of divergence, though not as extremely stable as in NVIDIA's case. Approximate Entropy, ranging from 0.54 to 0.61, indicates a moderate level of entropy, meaning that Intel exhibits a moderate degree of predictability-patterns are present but not fully clearly defined. Approximate Entropy for AMD, ranging from 0.37 to 0.44, indicates a moderate level of predictability-behavioral patterns are present but not fully stable. The Lyapunov exponent, ranging from 0.17 to 0.24, shows a slightly divergent system with low but positive values, indicating a certain degree of chaotic behavior. In conclusion, AMD's market behavior is characterized by a balance between predictable patterns and mild instability, making it a moderate yet dynamic system. For IBM, Approximate Entropy shows a significant increase—from 0.59 to 0.91—which clearly indicates growing unpredictability in market behavior patterns. At the same time, the Lyapunov exponent shifts from positive (0.15) to negative values (-0.31), signaling a transition of the system from a mildly chaotic state toward more stable dynamics. This combination points to a complex change: while the system's structure is stabilizing in terms of divergence, its local patterns are becoming increasingly irregular and harder to predict. IBM is in a specific transitional phase-structurally moving toward stability, while simultaneously experiencing an increase in internal chaos.

Table 2. Summary	of Chaotic Metrics	by Company
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Company	Lyapunov Exponent	Approx. Entropy	Hurst Exponent	Corr. Dimension	Lorenz Distance
AAPL	0.48 - 0.56	0.33 - 0.40	0.79 – 0.86	(error)	~457
MSFT	0.68 - 1.00	0.57 – 0.72	0.69 - 0.76	-2.5 to -2.9	Lower than Apple
GOOGL	-0.180.00	0.45 - 0.61	0.50 - 0.60	High complexity	Stable
NVDA	-1.5 – -1.6	0.30 - 0.44	0.60 - 0.70	N/A	Stable
INTC	-0.42 – -0.59	0.54 - 0.61	N/A	N/A	Stable
AMD	0.17 - 0.24	0.37 – 0.44	N/A	N/A	N/A
IBM	0.15 to -0.31	0.59 - 0.91	N/A	N/A	Stable

Microsoft showed the highest stability in terms of long-term predictability, indicated by its negative Lyapunov exponents and relatively low entropy values, suggesting a more consistent and predictable market behavior. Apple, on the other hand, demonstrated the best balance between growth and predictability, with chaotic traits combined with long-term stability and low entropy, indicating the potential for both stable trends and growth opportunities. NVIDIA and Google exhibited negative Lyapunov exponents and low to moderate entropy, reflecting their relatively stable and predictable dynamics, though their market behavior was somewhat less dynamic compared to companies like Apple and Microsoft. AMD, with more pronounced chaotic characteristics and lower predictability, was better suited for short-term and active trading strategies. Intel, offering moderate stability without significant fluctuations, represents a more conservative option with relatively predictable behavior. IBM, however, showed a sharp increase in entropy, signaling growing unpredictability despite indications of structural stability, suggesting that it may not be ideal for long-term positions.

CONCLUSION AND FUTURE WORK

This work presents a comprehensive system for analyzing chaotic patterns in financial markets, combining classical chaos theory metrics with artificial immune system algorithms for anomaly detection and market classification. The system not only detects chaotic behaviors but also classifies market states into categories such as "chaotic," "stable," or "predictable," based on the calculated metrics. By utilizing indicators such as the Lyapunov exponent, correlation dimension, approximate entropy, Hurst exponent, and the distance from a reference Lorenz trajectory, the system enables both quantitative and qualitative assessment of market stability, predictability, and dynamic transitions between different market states over time. This classification framework provides a deeper understanding of market behavior, highlighting periods of instability and offering insights for market prediction and risk assessment. The analysis reveals clear differences in the dynamic behavior of the companies under consideration. While Apple and Microsoft exhibit more pronounced chaotic characteristics—marked by high Lyapunov and Hurst exponents indicating long-term dependencies—companies like NVIDIA and Google demonstrate more stable and predictable behavioral patterns. Particularly notable is IBM, which seems to be in a transitional phase—shifting from mild chaos towards greater structural stability, while also experiencing an increase in short-term unpredictability.

From an investment strategy perspective, the results enable a practical classification of market options. If maximum stability is the goal, NVIDIA and Google stand out as the most reliable choices due to their negative Lyapunov exponents and low to moderate entropy values, indicating consistent and predictable dynamics. For those seeking a balance between growth and predictability, Apple emerges as the optimal option-exhibiting chaotic traits along with stable long-term trends and low entropy. Microsoft and AMD, with more pronounced chaotic behavior and lower predictability, are better suited for active trading and short-term strategies. Intel offers a more conservative option—stable and moderately predictable, without significant fluctuations. After results analysis we can conclude that IBM is not recommended for long-term positions due to a sharp increase in entropy, which points to growing unpredictability despite signs of structural stabilization. The proposed algorithm, a combination of artificial immune systems and chaos theory metrics, proved effective in detecting anomalous behavior and dynamic shifts without generating false alarms, further confirming the robustness of the proposed system. Interactive visualizations enable intuitive interpretation of complex results and contribute to a better understanding of the nonlinear processes that characterize modern financial markets. This approach represents a step toward the development of advanced tools for early instability detection and potential crisis forecasting, with potential applications in financial engineering, risk management, and strategic investment planning. Future research will focus on refining the classification system by incorporating additional market factors and expanding the scope to include more diverse financial instruments, such as commodities and cryptocurrencies. Further improvements can be made to the anomaly detection algorithms, enhancing their sensitivity to subtle market shifts without increasing the risk of false positives. Additionally, exploring the integration of machine learning techniques to complement the chaos-based analysis could offer deeper insights into market behavior, improving both the accuracy and reliability of predictions. The system could also be expanded to support real-time market monitoring and decision-making, enabling proactive responses to emerging market conditions.

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