**The Chaos Theory Trading**

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The stock market is known for its unpredictability, and identifying trends that can be challenging, even for experienced traders. However, the chaos theory provides a new perspective on markets behavior that can help traders identify patterns and trends. Chaos theory is a branch of mathematics that studies the behavior of dynamic systems that are highly sensitive to initial conditions. It suggests that seemingly random events can be understood through the analysis of underlying patterns and structures.

In algorithmic trading, chaos theory can be applied to identify trends in the stock market by using mathematical models that capture the underlying patterns of market behavior. One way to achieve this is by using indicators based on chaos theory. In this project, we will explore four such indicators: the Hurst Exponent, Fractal Adaptive Moving Average (FRAMA), Detrended Price Oscillator (DPO) and Chaikin Volatility Indicator.

By using these indicators, we hope to provide insights into how the chaos theory can help traders identify trends in the stock market. The remainder of this proposal will discuss the methodology we plan to use to analyze the data, and the results we expect to find.

In the project, we chose to run the indicators on the Tel Aviv stock market 125 since the stock market in Israel is a less competitive market. We wanted to check the quality of the indicators in a market where there is a low chance that this has been done in the past.

Chaos theory has been applied to financial markets since the 1980s. The theory suggests that the stock market is a complex system with a high degree of sensitivity to initial conditions, making it difficult to predict with traditional methods. However, the underlying patterns and structures in the market can be identified using mathematical models, such as those based on chaos theory.

Our indicators:

The Hurst Exponent is a key parameter used in the analysis of fractal structures. The Hurst exponent was introduced by Harold Edwin Hurst in the 1950s to study the Nile River's water flow. The Hurst exponent measures the persistence of a time series and helps identify the degree of long-term dependence in the data. In finance, the Hurst exponent is often used to identify trends and cycles in the market. A Hurst exponent greater than 0.5 indicates long-term persistence, while a Hurst exponent less than 0.5 indicates anti-persistence.

The Fractal Adaptive Moving Average (FRAMA) indicator is based on chaos theory. The FRAMA is a moving average that adjusts to the changing volatility of the market, making it more responsive to changes in trend. This indicator is a type of moving average that uses fractal geometry to dynamically adjust its smoothing period based on market conditions. It is designed to be more responsive to changes in trend and volatility than traditional moving averages.

When the closing price of the stock is lower than the indicator measured by N days we will buy. A sale will be made in the opposite case.

These two indicators are the main indicators that we tested and stabilized. The following two indicators are indicators that aim to identify volatility and therefore they were used in the work as additional information on the main indices and they do not stand as indicators on their own.

The Detrended Price Oscillator (DPO) is another indicator based on chaos theory. The DPO is an indicator in technical analysis that attempts to eliminate the long-term trends in prices by using a displaced moving average, so it does not react to the most current price action. This allows the indicator to show intermediate overbought and oversold levels effectively. Traders can use the estimated future peaks as selling opportunities or the estimated future troughs as buying opportunities.

The Chaikin Volatility Indicator is a measure of volatility that is based on the concept of chaotic behavior in financial markets. The Chaikin Volatility Indicator is the difference between two moving averages of a volume weighted accumulation-distribution line. By comparing the spread between a security's high and low prices, it quantifies volatility as a widening of the range between the high and the low price.

Overall, the literature suggests that indicators based on chaos theory can be useful in identifying trends and making trading decisions in the stock market.

**The topic selection process-**

At the beginning of the semester, we thought about 2 different ideas for carrying out the project. The first idea was to try to predict the trends in the market according to external shocks that occur. We thought of choosing a news site and based on the announcements that are published on it to perform an analytical analysis and see how the events that are published in the news affect the stock market. We thought to count the number of optimistic words that are published every day in articles and thus predict the trends. However, after the meeting with Nir, we realized that although the idea is very interesting, we do not have the knowledge and tools required to download and analyze the data that required.

Our second idea, which we also chose, is the selection of 4 mathematical and physical laws that will be implemented in the stock market, and we will see if they make it possible to predict the various trends in the stock market of Tel Aviv. In all scientific worlds, stock market prediction can and is already at the forefront. As a result, we decided to focus on laws and indicators based on Chaos theory only, so that we can show a world that is not fundamentally economic can give better results than the standard technical indicators in the market.

**Motivation -**

In the article " Hurst Exponent and Trading Signals Derived from Market Time Series", Czech Technical University, we can see an example of an experiment that was conducted with the aim of answering the question whether it is possible to construct a new technical indicator based on chaos theory which would bring more profit than some of standard technical indicators (MACD) that are often used.

They developed a new technical indicator MH (Moving Hurst) based on fractal dimension of time series, on Hurst exponent, and we evaluated the hypothesis that Hurst exponent of market time series can be successfully used as a technical indicator in a trading strategy. Exactly, it was used on existing data, and it brought more profit than using of MACD.

Since the differences between profits from the usage of MACD and MH were fluctuating, we used paired t-test statistics to test our hypothesis that MH brings more profit than MACD. We used the time series of profits generated by MH and the corresponding time series of profits generated by MACD for all stocks of DAX and for all stocks of NASDAQ as described in Section 5. We stated the following two hypotheses:

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They reject the theory H0 with possible error α = 1% for both Ddata collection (DAX and NASDAQ). The winning theory is MH, he has a greater income rate than MACD.

Similarly, they tested the hypothesis that the using of MH indicator brings more profit than the using of Buy & Hold strategy.

In both tests the results were unequivocal that MH was on average 7.85 times better in all tests. This article, the examinations made in it and their conclusions motivated us to focus on the law in the project. In addition, other studies we have seen have shown similar findings and a lot of interest around the chaos theory in the world of stocks that has developed in recent years.

**Methodology**-

The construction of our model and its analysis was carried out in 8 different stages:

1. Data collection – As already mentioned above, we tested our indicators on data of Tel Aviv Stock Market 125 for 15 years (01/01/2006 – 01/01/2021). We decided to collect 15 years data because we performed the tests on daily trading and after consultation, we decided that approximately 5 thousand results per share is a sufficient range of data so that we can optimally test our indicators.

We have created a database that collects for each stock in the last 15 years daily information on the following data: Open, High, Close, Low, Volume.

1. Indicator data – After creating a database on the stocks we have reviewed, we added 8 more columns to the data frame describing our indicators and strategy.

The first column returns for each stock the Hurst value of each day and it is calculated based on the 100 days that preceded it.

The second column named return describes the return value per share. The yield is calculated according to the closing price today minus the closing price of the stock the day before.

The third column called Direction receives 1 or -1 according to whether the stock price is in a good momentum or a bad one. Stocks will receive 1 if its price today is at least 5% higher than the 15 days average price preceding this day, -1 for opposite result, and 0 for others.

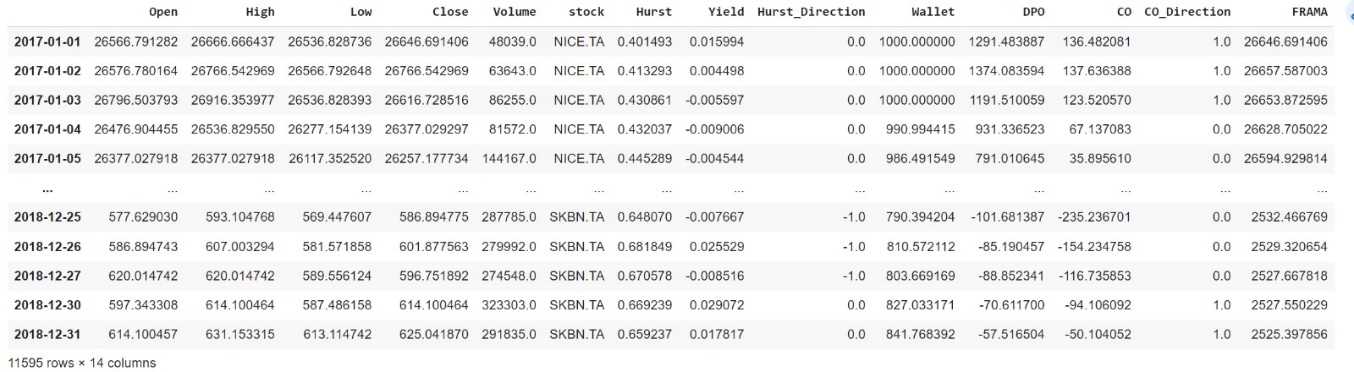
We tested our model on 100-day lookback windows as our indicator is also calculated.

The fourth column describes our wallet, the column shows each share what its value is in the wallet.

The fifth column called DPO it returns for each stock the DPO value of each day and it is calculated based on the 20 days that preceded it.

The sixth column called CO and it returns for each stock the CO value of each day and it is calculated based on the 20 days that preceded it.

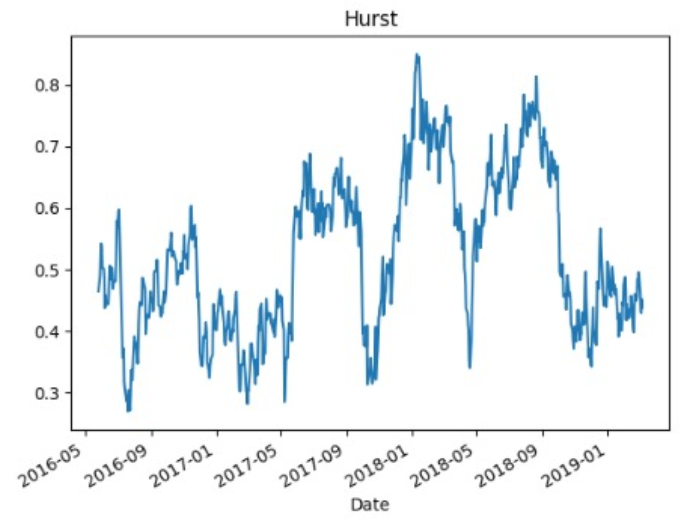
The seventh column called CO\_Direction and receives 1 or 0. He gets 1 if the closing price of the stock today is higher than 12 closing prices out of the 20 days measured before. Gets 0 when this does not happen.

The eighth column called Frama it returns for each stock the Frama value of each day and it is calculated based on the number of days preceded which changes according to the optimization.

1. Defining and dividing the times of IN and OUT – At this point we had divided the data we collected over 4 years into 2 groups based on dates. The first group is the IN group (2016-2018), on this group we will run all our tests and examine what is the best value of our indicator that will create the best stock portfolio.

The second group is the OUT group (2019-2021) on which we will perform the final run of the model, we will test him, after we have chosen a final value. Both the IN group and our OUT group are time periods of two years.



1. Examining the parameters on the selected times –  
   In these graphs we took a period from the in sample and showed the market's trend both on TA125 and on the hurst exponent indicator:

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As we can see in the graphs above, the data we collected, and our indicator, are both showing data that is full of reversals and changing trends.

In the graphs under the rad lines, emphasize the situation when the Hurst is equal to half or less, our stock is in a random walk as can be seen in the next graph. But when the Hurst value is closer to 1 the trend is constant and rises consistently as you can see in the second graph.

1. Building the strategy – We are building a strategy that will help us build an optimal stock portfolio that will help us predict the future trends, and then we can know whether to buy or sell the stock.

During the work on the project, we encountered several difficulties when we checked results and therefore, we often changed our strategy.

When we saw that we were not getting the results we aimed for in the Sharp index, we decided with the help of Dr. Koresh Galil to build a wallet as part of the strategy.

We started the wallet with about 102,000 dollars, which we divided equally among the 102 stocks that were included in the Tel Aviv 125 index for a certain period.

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Another change we made after testing our model and strategy is the change from 4 main indicators to 2. We did this due to the understanding that a single indicator cannot provide enough information about the market, so we also saw in the results. In addition, when we presented the work for the first time, we received criticism that we need to think about how we present and unite the indicators so that in the end they represent the goal together.

1. Optimization - The purpose of the model is to get the stock portfolio with the best Sharpe ratio. To train and test the model, we built an optimization, following which we will decide whether to sell the stock, buy it or whether to stay in the same position.

Hurst:

Buy- if: hurst > value & direction =1 & (DPO > 0 or CO\_Direction =1)

Sell- if: hurst < value & direction = -1 & DPO < 0

Hold- when between

FRAMA:

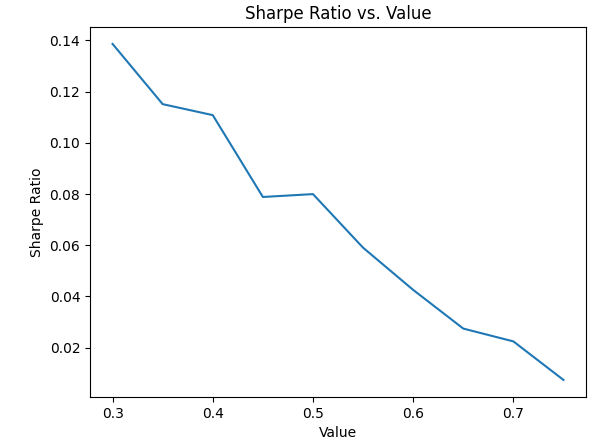
Buy- if: FRAMA > yesterday's close & position<=0 & (DPO > 1 or CO\_Direction==1)

Sell- if: FRAMA < yesterday's &position==1 & DPO < 0

If we are not in any of the situations, we will not change our stock portfolio and will remain in the same position.

Another test that we added to the model's strategy to improve it is the Stoploss test. This test takes place when the model receives a buy result. Its purpose is to verify whether the share price does not experience too significant changes so that it is in a dangerous situation and may endanger our share portfolio and therefore we should stop buying.

stop\_loss\_pct = 0.05



The reason why for now we are getting a better Sharpe ratio for a smaller Hurst threshold is that it allows for more frequent buy and hold transactions. When we have a smaller Hurst threshold, we are more likely to have our Hurst indicator above the threshold, which means we will buy the stock. This results in more frequent transactions and a smaller standard deviation, which in turn leads to a better Sharpe ratio.

1. Processing results – After examining the model and running it, we calculated important values ​​for the stock portfolio to examine the results obtained. We calculated the standard deviation, Sharpe ratio and return per share in the portfolio.  
   The results can be seen in the following graphs:

Hurst indicator-

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FRAMA indicator-

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1. Train- test model–
2. Create the labeled data for training- we selected a specific period, typically at the end of the month and labeled the data based on the returns observed in the following month. This labeling process allowed us to create a target variable that represents the future performance of the stocks.
3. Train the model- We utilized the HistGradientBoostingClassifier, setting the maximum depth to 4 and the random state to 0, which helps control the complexity and randomness of the model. We trained the classifier using the training dataset, where we used the indicator features (Hurst, CO, DPO, FRAMA) as inputs and the actual target values as the output variable.  
     
   By fitting the classifier to the training dataset, the model adjusted its internal parameters to optimize its ability to predict the actual target values.
4. Test the model- using the trained model to make predictions on a subsequent month's data and comparing the predicted values with the actual returns of the follow-up month to assess the accuracy and effectiveness of our model.

We then repeated this process six different times in 2017. For each occasion, we labeled the data based on the subsequent month's returns and trained the model using the corresponding training dataset specific to that period.

Examples of results from 2 different months-

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**Conclusions-**

Fixed time windows: We ran the model in fixed time windows but we think it would have been better if we had ran the optimization time windows as well.

Improving the model:

* Running the train - test model every X months on order to recommend the best stock portfolio
* The distribution of the wallet between the shares according to weights and not in an equal manner

Results: We expected to get much higher Sharp Ratio results and we are sure that we will be able to achieve them with the help of the things written above and the changes that need to be made.

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