Visual Signatures for Financial Time Series

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ABSTRACT
Information visualization techniques have been applied to many research fields in recent years. This paper introduces the concept of visual signature for financial time series. Unlike other information visualization, visual signatures are designed to more proactively reveal visual patterns of market data. Previous research on visualizing financial time series is discussed and compared. This paper shows how the concept of visual signature helps professional analysts obtain instant and useful visual messages from it.

Categories and Subject Descriptors

General Terms
Design, Human Factors.

Keywords
Information Visualization, Visual Analytics, Financial Time Series.

1. INTRODUCTION
This paper introduces the concept of visual signature for financial time series. The word, signature, is defined as “something (as a tune, style or logo) that serves to set apart or identify; a characteristic mark” in the online version of Merriam Webster dictionary. In terms of financial time series, we want to present market data in the form of a signature from which we can easily identify the dynamics of the market. What a visual signature brings to us is a unique pictorial presentation. The concept is similar to giving an identity to an entity, such as the logo of a company, the symbol for an event. Conceptually a visual signature differs from information visualization in its ultimate purpose. The task of information visualization is to present data in a readable visual form which may or may not be unique, whereas a visual signature arranges data in a unique visual form conveying a message to the user. The goal is to communicate with the user through unique visual patterns.

The notion of visual signature was conceived during the course of our research project in analyzing financial time series. Our research interest in the project was in applying visual approach to assist data analysis, as opposed to textual statistical analysis. In order to elicit the core issues in visual analysis of financial time series, we first investigated the characteristics of financial time series by collecting analysis reports from various reliable sources. We then walked through the key scenarios that financial analysts pay attention to. We formalized the visual design issues by creating a list of requirements based on these scenarios. The requirements served as a guideline for reviewing current visual methods and previous related work. We found that there is a gap between currently available visual tools and analysts’ needs. Most current visual tools fulfill partial needs of the financial analysts. We thus were motivated to investigate further by examining visualization components against the identified requirements and developed a set of visualizations for financial time series. The outcome of our research is a working visualization environment for exploring financial time series. Owing to space limitation, this paper presents the partial result of our research - the concept of visual signature. Our contributions are

- We created a visual signature for the main market index using the structure of Fermat’s Spiral. It enables investors to visually define daily market overall performance according to the dynamics of market trading activities.
- We created a visual signature method for displaying single stock data using the Tai Chi symbol. Based on this visual signature, investors will be able to group stocks with similar short-term trading activities.

We will begin our discussion by firstly reviewing the related work in information visualization in Section 2. Section 3 describes the motivation of our work. In Section 4, we proposed the galaxy visualization for the main market index and Section 5 presents the Tai-Chi visualization for displaying single stock data. Section 6 discusses the evaluation on these visual signatures from investors and we conclude the paper in Section 7.

2. RELATED WORK
Information visualization techniques have been applied to many research fields in recent years. There are a number of methods to visualize information, such as area-based, pixel-based, tree-structure, geometrical shapes, and node-links. Since our research theme is on financial time series data, we will focus our discussion within financial and temporal related visualizations. The following subsections will review previous work related to our research.

2.1 Area-based visualizations
Several previous researches used area-based visualization techniques to display information. Alsakran et al. [2] applied visual technique to examine the relation between mutual fund performance and fund characteristics such as asset size, cash holding, loads, expense ratios and turnover. They used a weighted density-based distribution map to plot fund distributions on a colored map. Instead of using evenly distributed cells, they
assigned each cell in the display space with a weighted value. Data cells with higher density are given with more weight so as to fully utilize the available display space. This method basically uses variable scaling to display data. It is similar to the fisheye technique that uses a fisheye lens to zoom in on the display space to obtain further details. Although the display space is visually distorted, it offers a way to focus on more relevant data. Lin et al. [12] also used the fisheye technique to provide a context and focus feature for currency exchange data plotted on a two-dimensional line chart.

FinVis developed by Rudolph et al. [17] is a visual analytics tool that helps the individual improve decision making by visualizing aggregate risk alongside a traditional wealth-time plot in a casual context for personal finance data. Its main visual display was inspired by ThemeRiverTM [7]. Instead of visualizing theme magnitude, FinVis shows risk magnitude for financial decisions. This type of visualization presents data with larger values using more aggregated space areas against timeline. Different color shadings are used to show various types of data. In terms of financial time series data, this method may be applied to display daily performance of stock sectors, but it is not suitable for displaying the performance of a single stock due to the number of stocks is usually a large number. Plotting the entire data set is not logical as the system will eventually run out of available color shadings to differentiate data.

The Treemap visualization [18] is a widely used visual technique in financial markets. The website Smartmoney.com provides an interactive Treemap views (Market Map) on the most current stock market data. It visualizes the most active and inactive market sectors in a single view. Huang et al. extended Treemap visualization from a 2D to 3D display for fraud detection [9]. They used 3D Treemap to monitor the real-time stock market performance and to identify a particular stock with an unusual trading pattern. When a suspected pattern is found, they used social network visualization to conduct behavior-driven visual analysis.

The Treemap visualization is close related to our work. It is a great tool for visualizing the overall performance of stock market data. Two types of color shadings clearly show the sectors with most positive or negative performance, and the size of the display area indicates the capital size of the stock. During the course of our research, we inquired of professional stock analysts about the usefulness of Treemap. They pointed out that it is not easy to compare stock sectors with mixed performance. When two color shadings are mingled within the same stock sector area, it is difficult to tell the performance of the sector. Visualizing performance simply by color shading might not be the best solution as a blurring effect appears after staring at the market map for a longer period of time, which makes the comparison of stocks difficult.

### 2.2 Pixel-based visualization

Pixel-based visualization technique has recently gained more attention due to its ability in displaying a large set of data within a limited display space area. Ziegler et al. [25] developed the Performance Matrix visualization to apply visual analytics on the financial market. The performance matrix is arranged as a rectangular box with x and y axes where x-axis represents time scale and y-axis represents holding period. Each point in the x and y coordinate is colored according to its growth rate. The resulting representation clearly shows the overall performance of the defined period by its color variation. The Groove visualization is a pixel-based visualization proposed by Lammarsch et al [13]. It provides a calendar view with color and opacity overlay to visualize temporal patterns. The Circle view proposed by Keim et al. [11] uses pixel-based method to cluster stock data with similar performance. On the same display, it provides stocks prices at different time granularity. Through the use of different color shadings, segments of similar data values can be easily shown. One noticeable issue with the Circle view is its scalability. The number of displayable data elements is limited by the display space. It is more suitable for visualizing small amounts of data.

Hao et al. [8] used a pixel-based visualization to display a large set of time series data. Their visualization provides multi-resolution data displays. Their method can be viewed as a hierarchical Heatmap visualization. Heatmap is a visualization that simultaneously reveals row and column hierarchical structure in a data matrix. The earliest publication on the Heatmap method can be dated to Loua’s work in 1873 [15, 23]. One of its advantages is that it allows data rearrangement and clustering by means of permuting the data matrix. For example, the Circle view discussed earlier used a clustering technique to group stock prices.

Our observation on pixel-based visualization is that it possesses at least two advantages:

- It is able to visualize a large set of data within a limited space.
- It enables a full utilization of color shading method to pin point hot spot data areas.

In terms of financial time series data, pixel-based visualization is suitable for visualizing historical stock prices over a long period of time. It should be able to enhance analyses on stock trading patterns.

### 2.3 Geometry-based visualization

Geometrical objects have always been used for visualization, for example, line charts, bar charts and radar charts are the visualization methods we often encountered in our daily life. Extending the idea on geometrical objects is the use of mathematical curves. Weber et al. [22] used spirals to visualize time series. They plotted stock data on spiral curves using different color shadings to show possible trading patterns. Chin et al. [4] also developed the dynamic spiral timeline visualization to show cell phone call data. Visualizing data using spiral curves is surely a good method for displaying temporal data. We will show quite a different way of utilizing spirals to visualize stock data in Section 4.

The TimeWheel visualization [20] displays temporal data using circular axes. The basic idea is to present the axis of time in the center of the display, and to circularly arrange the dependant axes around it. The surrounding dependant axes hold the values of data variables. Basically, the TimeWheel visualization is a type of node-link visualization. The advantage of using node-link is that it enables tracing of data values. In addition to using different color shadings, length and direction can also be used for data representation.

One other node-link type visualization is the ActiviTree [21] that provides an interactive exploration environment for the systematic identification of sequences in social science activity diary data. It allows the user to interactively select interested activities and study further on other linked activities. In our opinion, this type of visualization is suitable for data analyses requiring more user interactions.
One more geometry-based visualization worth mentioning is the VisAlert system [6]. The VisAlert visualization is developed to visualize problems related to computer network systems. It uses multiple circles to indicate temporal attributes and connects them to topological data with links. One issue we noticed is that the VisAlert system is a good tool for visualizing correlation of limited amount of network alerts. It, however, might not be suitable for a large set of data as the issue of visual clutter will appear when more links are drawn.

2.4 Multidimensional visualization
Multidimensional visualization is an alternate way of visualizing data. Dwyer and Gallagher [5] proposed a two-and-a-half dimension method to visualize changes in stock portfolio datasets. Their system provides different two-dimensional views to show data movements and data changes. Their “columns and worms” metaphor maps stock sectors to columns and worm-like connectors to show fund transfers in a given time period. This method is suitable for capturing the movement of data but it might not be an efficient tool for daily investment monitoring. In our view, the movement of data can be more effectively performed using just a two dimensional display.

Thakur and Hanson [19] proposed a three dimensional visualization. Their method stacks temporal data using a column of discs to show geographical related information. It clearly displays the variation of data values thorough different color shadings and disc sizes. Their method, in our opinion, can also be applied to financial time series but it will require more user interactions to make it efficient.

The Market Topology visualization is a commercial product that uses a three dimensional tree-like visualization to show stock data [10]. It groups related stocks in tree branches and uses red and green color to indicate the performance of stocks. Its main advantage is the ability to cluster related stocks in a tree branch, but it also creates visual clutter.

2.5 Summary
Information visualization has recently gained more attention in the form of visual analytics by researchers. Many research papers have been published in the last few years. In this section, we limited our discussion on visualizing financial and temporal related data. More reviews on visualizing time-oriented data can be found in the review by Aigner et al. [1]. Each proposed visualization technique was developed for a particular purpose or serves to solve a specific problem. Our work differs from them in the aspect of viewing purpose. We present information in the form of visual patterns based on the given data. The following section will explain the idea of our work.

3. MOTIVATION
A signature is a distinctive mark that serves to set apart. Our idea is to develop a visual system that enables the user to set a characteristic mark for market data. The concept is similar to creating a logo of for a company, a signature of a person, or a symbol for a particular aggregation of things. Visual signs have long been used for communication since the ancient times. One of the earliest visual symbols was developed by the people living in Mesopotamia around 3100 B.C. They used the barley signs as shown in Figure 1 to keep track of how much barley was taken away.

Another example is the Phaistos Disc which is a disk of fired clay from the Minoan palace of Phaistos on the Greek island of Crete, possibly dating to the second millennium B.C. As shown in Figure 2, there are a total of 241 tokens on the disc, comprising 45 unique signs. Many of these 45 signs represent easily identifiable daily used objects and things.
From the set of pictograms, we can clearly see the visual sign resembling a person is the key figure. Each pictogram represents a sport activity by mimicking a person’s body movement accompanied with a sport symbol. It is simple but effectively conveys the underlying message. Referring back to financial time series, it would be desirable to have such pictograms to show market performance so that we can easily detect visual patterns in the market movements. However, unlike visualizing sport activities, what we are dealing with are numerical data values rather than an identifiable entity. In Section 2, we reviewed the related work for displaying financial or time-oriented data. They were designed to enable visualizing data which may or may not have a specific visual pattern. For example, in Figure 4 we show two rings visualizations for two different market days. The rings visualization was developed in our previous project [14]. The ring filled with black color is the market index. The mark index performance on both days was about 1.7%. One noticeable difference between the two rings visualizations is that more stocks performed better than the main market index in the upper rings visualization. In the lower rings visualization, the main market index has a larger ring than most of the stocks, which means it performed better than most of the stocks. Although the rings visualization provides a good interactivity for exploring data, it is not easy to detect any pattern from these displays.

Let’s take another example from the treemap visualization for the US stock markets. Figure 5 shows two treemap visualizations for the US stock market generated from finviz.com. The main index performance on both days was about 1%. The most obvious difference on the two displays is few stocks with large capitalization size performed differently on both days. It is difficult to spot any visual pattern from the displays.

Different drawing techniques can often create different visual meanings of the same object. In Figure 6, we depict a figure of a human body using slightly different center lines. The left drawing shows a person who is in a walking motion. On the right, we tilt the center line to the right, and swing the hands and one leg upward to match the natural body movement. The drawing result.
shows the person is in a running motion. Applying the idea of drawing techniques to information visualization, we may create different visual meanings from the same set of data. In the next two sections, we will show our method to reveal visual patterns by means of a visual signature. We developed two levels of visual signatures – one for the overall stock market performance and another for individual stocks. Our work is close to the work in the field of semiotics where signs are studied and analyzed in terms of their semantics, syntactics and pragmatics [3]. The idea of visual signature is about communication through visual displays whereas the field of semiotics is on the study of signs and their relations.

4. THE GALAXY VISUALIZATION
The basic approach for making a visual signature is that the visualization should follow a traceable drawing rule through which we may set unique visual display for different sets of data. In geometry, sophisticated shapes are drawn based on some mathematical equations. We reviewed a large number of geometric shapes and selected Fermat’s spiral as the basic form in our design. The basic form of Fermat’s spiral is shown in Figure 7. We will explain the reason of using it in detail below.

![Figure 7. Fermat's spiral.](image)

The polar equation of Fermat’s Spiral is 

$$ r = c \times \sqrt{\theta} $$

where $r$ is the radial distance, $c$ is the angle from the zero-degree line, and $\theta$ determines how tightly wound is the spiral. Helmut Vogel [24] introduced an angular divergence factor to the equation. The modified polar equation is

$$ r = c \times \sqrt{n}, \theta = n \times \alpha, n = 0, 1, 2, \ldots, n_{\text{max}}, $$

where $r$ : is the distance between the origin of the polar coordinate system and the nth node.

c: is a spacing constant describing the placement of nodes.

$n$: is the ordered number of nodes counting outward from the center.

$\theta$: is the angle between a reference direction and the position vector of the nth node in the polar coordinates. The origin of the polar coordinate system is at the center of the spiral pattern.

$\alpha$: is the angular constant for the spiral pattern.

By varying the value of $\alpha$, we may obtain a rich set of different floral patterns. Figure 8 shows four unique spiral patterns with $\alpha = 8, 21, 103,$ and $137$. This interesting property makes the Fermat’s Spiral as our ideal way of creating the visual signature for stock market data. The most important factor is that we may create a different visualization by simply changing the angular value $\alpha$.

![Figure 8. Fermat’s spirals with four different patterns.](image)

Leading stocks and leading sectors provide some clues on the current market focus. Professional investors observe leading stocks and sectors in a number of ways. The market index of a stock market is composed of a set of stocks with different weight contributions. If, for example, a stock with more weight distribution is among the leading stocks or belongs to the leading sectors, and the trend of the leading sectors is going up in the near term. It is highly possible that the index will rise in the near term. By observing the movement of leading stocks, we may get a hint on the next market movement. The usual case is that market performance often lies on few leading stock sectors. Thus, making a visual signature for stock market performance through visualizing the leading market sectors is an ideal approach. We studied the Fermat’s spiral carefully by adjusting the angular $\alpha$ value, and found interesting results. The drawing of the Fermat’s spiral is from the center drawing outward. Setting the angular $\alpha$ value to 5, 191, 233, and 273, we got a set of spiral patterns with one, two, three, and four outward lines respectively. Figure 9 displays the four spiral patterns. In Figure 10, we set the angular $\alpha$ value to 358, 179, 239 and 271. We obtained a different set of spiral patterns with varying outward lines. The patterns in Figure 9 are more close to floral patterns, whereas the patterns in Figure 10 are simple spirals. Floral patterns naturally give an impression of cheerfulness. They are well-suited to represent positive market performance. The simple spiral patterns can be used to represent negative market performance. We developed a visualization called the galaxy visualization as a visual signature for overall market performance based on the floral spiral idea.

![Figure 9. Fermat’s spirals with flowery patterns.](image)
Figure 10. Fermat’s spirals with incremental spiral patterns.

Figure 11 shows an implementation of the galaxy visualization. The center depicts a positive market performance with three leading sectors. The data points are arranged by their capitalization sizes. We used different size of dots to represent large, medium and small capitalization sizes. The outer rings display the market data in non-leading sectors. Data points on the outer rings are arranged according to their performance. The rings emulate the Milky Way galaxy. Our implementation allows the user to set viewing angle, size of data point, the value range for determining leading sectors and the angular $\alpha$ values for the matching numbers of leading market sectors. The viewing angle in the figure is about 40 degree looking down to the center. Figure 12 shows a display with the viewing angle at 10 degrees. The user may check the performance detail of each stock by moving the mouse pointer to the data point as shown in Figure 13. Figure 14 shows a negative market performance with six leading market sectors. As the implementation allows the user to set the angular $\alpha$ values, they may define a customized set of visual signatures for different market performance.

In Section 3, we discussed the difference of visual signature and other visualization methods. Let’s illustrate the concept again by comparing the galaxy visualization with the rings visualizations in Figure 4 and the treemap visualizations in Figure 5. As discussed previously, the market index performance on both days was about 1.7%. From these displays, we are unable to see any visual pattern on both days except the performance comparison. We plotted the same set of data using the galaxy visualization in Figure 15. We can clearly see that Figure 15.(a) shows eight leading market sectors on that day. And Figure 15.(b) indicates only three leading market sectors. The image displayed in the galaxy visualization presents much more direct message.
Although the galaxy visualization is designed to reveal visual patterns through leading sectors, it does not lose information on the stock data of non-leading sectors. We may follow the outward rings to find the performance of the stock in the non-leading sectors. In our current implementation, we arranged the stock data of non-leading sectors by their performance. We may revise the implementation by grouping stock data in sectors. The visualization method is flexible in terms of displaying market data.

Comparing to the rings and treemap visualization, the galaxy visualization more proactively displays visual patterns of the market data. The goal of visual signature is to present data in a unique form. As we described in the introduction, visual signature differs from other information visualization in its visual design purpose. What we demonstrated here is one way of presenting financial time series in the form of visual signature. In our view, more visual signatures can be created as long as the design goal is properly focused.

The construction of the galaxy visualization involves three steps. We first need to obtain the overall sector performance with the following calculation:

\[
\text{Sector performance } P_s = \text{sum}(P_n \times V_n/V_{sector\_total}), \text{ where } \\
P_n: \text{is the stock code} \\
V_n: \text{is the percentage of one day movement for stock } n. \\
V_{sector\_total}: \text{is the total trading volume for stock } n.
\]

The next step is to determine the number of leading sectors according to the value range specified by the user. The performance of the main stock market index decides what type of pattern to be drawn. If it is positive, the visual signature should be drawn as a floral pattern. Based on the number of leading sectors calculated, we look up the matching angular \( \alpha \) value defined by the user. If the market index is negative, we look up the \( \alpha \) value on the negative value definition table. As the drawing of the spiral is starting outward from the center, we need to arrange the drawing sequence of data points from different sectors. Figure 16 shows the center of a spiral with three outward lines. We number the drawing sequence to show how the spiral is formed. It starts from the center where it is marked the number “0”. It then draws the second data point at the number “1”, and it continues to draw at the number “2”, “3”, “4”, “5”, “6”, and so on.

Suppose that we have three leading sectors. Each outward line is to be formed by stocks of the same sector. The drawing sequence is taking data from each sector in rotation. In our implementation, we sort the data by its capital size within the same sector and place the data into a queue. The program picks data from each queue in rotation and draws the data point on the screen. The placement of the data point is using the following parametric equation of the Fermat’s spiral:

\[
\begin{align*}
y(n) &= v \times c \times \sqrt{n} \times \sin(\alpha n \times \alpha), -1 \leq n \leq 1 \\
x(n) &= c \times \sqrt{n} \times \cos(\alpha n \times \alpha)
\end{align*}
\]

where \( c, n, \alpha \) are as described in the polar equation above, and \( v \) is an added parameter for setting the viewing angle. If the value of \( v \) is set to 1, the viewing angle is directly from the top. The value of \( v \) is set to 0, the viewing angle is from the side, and we should see a cluster of data points aggregated on the horizontal line.

The third step is to draw the outer part. In order to set the outer rings of data points on the same plane where the inner part lies, we applied the same parametric equation with a fixed \( \alpha \) value. That is, we draw a second Fermat’s spiral on the outer part. We set the angular \( \alpha \) value to 249 as it yields more widespread data points. We arrange the remaining data from non-leading sectors in the order of the percentage change in stock price. These data are then placed onto the screen from the outmost location back to the inner part. The outmost location number is the sum of the total number of inner points plus the total number of outer points. This number is large enough to avoid overlapping the two spiral patterns.

5. THE TAI-CHI VISUALIZATION

Many different factors can affect stock prices. The price of a healthy stock sometimes fluctuates with the market trading movement despite of its solid fundamental financial record. In our observation, any of the stock markets around the globe has its own pace. If the price of a stock rises up sharply in a very short period of time, a profit-taking action will soon follow. If the price of a stock drops steeply, a rebound of purchasing action will come after. The Hong Kong Hang Seng stock market allows investors to perform short selling actions. Short selling is an investment option that investors can borrow shares of a stock from a security trading company and return them back at a mutually agreed date. Usually, short selling is betting on the decline of the price of a stock in the near term. When the investor borrows shares, he/she sells out immediately. At the time of returning date, the investor repurchases an equal amount of shares and returns them back to the security trading company. If the price of the stock declines by

\[
V_{sector\_total} = \text{sum}(V_n)
\]
10%, the investor gains 10% profit. Short selling provides investors a way of betting on negative performance of the market. Our view is that the performance of a stock market is the tug of war between the forces of regular stock purchasing and short selling. Regular stock purchasing bets on the positive side, whereas short selling bets on the negative side. Based on this concept, we developed the Tai-Chi visualization to visualize the forces of Yin and Yang (negative and positive).

Figure 17 shows an example of the Tai-Chi visualization. Data points are placed along the middle curve line based on their performance. The left side is negative and the right side is positive. The middle curve line holds data points with zero change in price. Data points with more changes are farther away from the center line. We divide the chart into upper and lower parts from the circle center. Data points on the lower part are more recent. Within each part, we connect data points with red or green lines. Data points on the positive side are connected if there are more points on the positive side. In Figure 18, the upper part has more data points on the positive side, a red line is drawn to connect data points on this side. This line we name it as the Tai-Chi line. It highlights the overall performance of a stock.

The Tai-Chi visualization is designed to create a visual signature of a stock. It serves as a symbol for a stock. By looking at the Tai-Chi line, we can identify the recent performance of a stock. Our implementation allows the user to check the detail information of each data point by moving mouse point onto it. We also developed an analysis feature for grouping stock with similar performance based on the Tai-Chi chart.

The grouping process starts by firstly classifying stock data with the color of their Tai-Chi lines. Four types of Tai-Chi lines are possible – green-green, green-red, red-green and red-red. Within each type, we use the Euclidean distance to compare the similarity of two stocks. It is calculated using the following:

$$E(p,q) = \sqrt{\sum_{i=1}^{n} (q_i - p_i)^2}$$

where \(n\) is the number of trading days, \(q_i\) is the price of the stock \(q\) on day \(i\), and \(p_i\) is the price of the stock \(p\) on day \(i\).

The user may specify the value of \(E\). Within the value of \(E\), the movements of two stocks are considered to be similar. Figure 18 shows a sample result of our grouping implementation. We list three lines of stocks and stocks on the same line belong to the same group.

The Tai-chi visualization is constructed by drawing one big circle and two small inner circles. The upper inner circle is used for drawing data points from the first half of the user specified date period, and the lower inner circle is used for the second half of the data period. As shown in Figure 19, we used different radiuses to place the data points. The drawing process starts by calculating daily percentage of price movement. We get the positive price change range \(D^+\) and negative price change range \(D^-\). On both sides, we define four equal intervals of price change. The value of each interval on the positive side is the value of \(D^+\) divided by four. Likewise, the value of each interval on the negative side is the value of \(D^-\) divided by four. We set the initial radius to \(r\) which is the radius of the middle line. The radius of the data point on day \(i\) is calculated by

$$r_i = r + p_i \mod \frac{D}{4} \times c$$  if \(p_i > 0\), and

$$r_i = r + p_i \mod \frac{D}{4} \times c$$  if \(p_i < 0\),

where \(r\) is the radius of the middle line, \(p_i\) is the price change on day \(i\), and \(c\) is a constant value for setting the interval distance.

The angle of a data point is calculated as \(\theta = \frac{180^\circ}{N}\), where \(N\) is the total number of trading days in the upper or lower part.
6. EVALUATION
In order to evaluate our method, we ran a tutorial of our system to a group of five professional analysts. We then gave them a questionnaire to fill in. The reason for using a questionnaire as a way of evaluation is because professional analysts always know what features they need. As discussed in the introduction, we developed a set of visualizations for financial time series. The galaxy and Tai-Chi visualizations are among the set of visualizations in our system. The survey was conducted to evaluate the entire set. This paper shows the partial results related to the two visualizations discussed. For the purpose of comparison, the evaluation on the rings visualization is included.

The questionnaire is based on the work by Arnold M. Lund [16] and has been used by many companies around the world. It includes four areas of interests – usefulness, ease of use, ease of learning, and satisfaction. Each area has a list of questions which are listed below:

1. Usefulness
   1.1. It helps me be more effective.
   1.2. It helps me be more productive.
   1.3. It gives me more control over the activities in my life.
   1.4. It makes the things I want to accomplish easier to get done.
   1.5. It saves me time when I use it.
   1.6. It meets my needs.
2. Ease of Use
   2.1. It is easy to use.
   2.2. It requires the fewest steps possible to accomplish what I want to do with it.
   2.3. It is flexible.
   2.4. Using it is effortless.
   2.5. I can use it without written instructions.
   2.6. Both occasional and regular users would like it.
3. Ease of Learning
   3.1. I learned to use it quickly.
   3.2. I easily remember how to use it.
   3.3. It is easy to learn to use it.
   3.4. I quickly became skillful with it.
4. Satisfaction
   4.1. I am satisfied with it.
   4.2. I would recommend it to a friend.
   4.3. It works the way I want it to work.
   4.4. I feel I need to have it.

The participants were asked to give a score of 1 to 5 for each question. A score of 5 is granted as the best score. We calculated the average scores and show the results in the following table:

<table>
<thead>
<tr>
<th>Questions</th>
<th>Rings</th>
<th>Galaxy</th>
<th>Tai Chi</th>
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<td>3.4</td>
<td>2.8</td>
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<td>3.8</td>
<td>3.4</td>
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<td>4.2</td>
<td>3.8</td>
<td>4.0</td>
</tr>
<tr>
<td>B.2</td>
<td>4.2</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>B.3</td>
<td>4.0</td>
<td>3.8</td>
<td>3.0</td>
</tr>
<tr>
<td>B.4</td>
<td>4.2</td>
<td>3.8</td>
<td>3.2</td>
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<tr>
<td>B.5</td>
<td>2.8</td>
<td>2.4</td>
<td>2.6</td>
</tr>
<tr>
<td>B.6</td>
<td>4.2</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Average</td>
<td>3.93</td>
<td>3.57</td>
<td>3.37</td>
</tr>
</tbody>
</table>

We are more concerned with the usefulness and satisfaction categories as they are directly related to the design of our visualization. The ease of use and ease of learning categories are more related to the design of user interface which can be improved at a later stage.

The galaxy visualization received moderate scores comparing to the rings visualization. The participants told us that the visual signature idea was interesting. They were pleased with the design of the visualization as it helps them immediately see the market performance, and they would use it as an overall performance display. The Tai-chi visualization received lower scores on the usefulness and satisfaction categories. As the participants were all professional analysts, they are quite familiar with the background of most actively-traded stocks. The Tai-chi visualization becomes less important. The rings visualization [14] was designed to provide an interactive visual exploration on daily market data. The participants found it useful in their daily work. Despite of the scores of the two visual signatures being lower than the rings visualization, both visualizations still received a total average score above 3. We are encouraged and will continue our work in this path and improve them based on their feedback in the future.

7. CONCLUSION
This paper has discussed the concept of visual signature. Comparing to other information visualization methods, visual signatures are designed to more proactively reveal visual patterns of market data. Two visual signatures were proposed. The galaxy visualization, based on the Fermat’s spiral, displays the overall market performance. The Tai-Chi visualization presents single stock data over a period of time. We evaluated our concept by taking a questionnaire from professional analysts. The result was close to what we expected. The participants would use the galaxy visualization as a way of viewing the overall market performance. Our future work will be taking the concept to other areas of study.

8. REFERENCES


