Distinguishing Information from Noise is the common problem for signal analysis technology across applications as diverse as control of robot devices, digital communications and autofocusing cameras.

More than half a century of engineering and mathematical developments and the progress made possible by modern computational resources has produced a large body of 'signal processing' technology.

Omega Metrics® Market Trend Analysis is the result of our enhancements and adaptations of this technology to address the problem of identifying trends in financial markets. This note describes the background to our approach.

Extracting Information From a Noisy Signal

The following 'thought experiment' illustrates the problem and the solution we have designed for financial data.

Imagine that we are observing a robot which is designed to follow a series of straight line paths with periodic changes of direction producing a zig-zag trajectory. The robot's planned path is a straight line but it deviates from the plan when it hits an obstacle. Plotting the daily position of the robot results in a graph (Figure 1) that runs roughly from the bottom left toward the top right on a graph–like a stylised version of a financial time series. (See the Appendix for the details of the robot trajectory.)

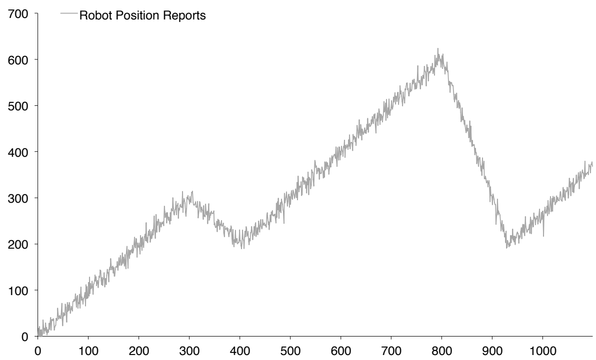

Figure 1. Plot of positions of the robot measured in meters north (vertical axis) and east (horizontal axis) of the starting point.

What we observe is the 'noisy' path obtained by regular observations of the robot's position. The signal processing problem is to deduce the planned trajectory from these observations.

As the robot's planned trajectory is made up of straight lines, it should not be surprising that linear regression gives a good approximation to each leg of the planned trajectory after enough data has been accumulated. In the first leg of the path it takes a linear regression 100 observations to see that the plan is to head north-east.

Using a rolling data window of 100 points this continues to accurately identify the plan until the robot reaches its first turning point. Then it makes what eventually becomes clear is a change of direction from north-east to south-east. But here the linear regression runs into trouble. It needs about 50 observations to confirm the change of direction and by the time it has recovered its previous accuracy the robot makes another change of direction.

This illustrates an inevitable trade-off between accuracy and lag. A shorter data window would identify changes in direction more quickly, but the noisy nature of the observed positions means that we are forced to use a longer window if we want to have a precise estimate of the planned path in each segment. Even though the robot's planned path is made up of straight lines, linear regression is not the best approach to this problem. Signal processing technology that incorporates feedback to adapt to changes in the data is what is needed.

Extracting Trends from Financial Data

Financial data such as daily close prices has no underlying deterministic trajectory–but the techniques of signal processing can be employed by treating it as if it did. Our Trend Indicators are designed to respond to changes in the shape of a 'virtual trajectory' in financial time series data to identify transitions from upward to downward trends in price.

Our approach uses a combination of averaging to smooth the noisy signal and feedback to reduce the lag produced by smoothing to produce reliable indicators of transitions between rising and falling prices. We illustrate this by applying our generic Short Term Trend Indicator to the robot position time series.

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Reading The Trend Indicator

Figure 2 shows a Short Term Indicator (which uses a rolling data window of 150 observations) applied to the robot position data.

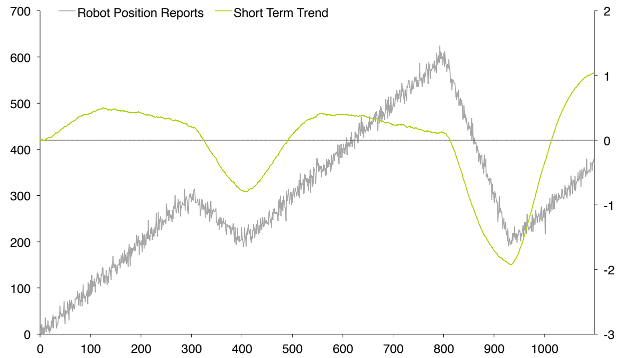

Figure 2. The Omega Metrics® Short Term Trend Indicator (right hand scale) calculated from the time series of position updates. The Indicator signals a change in direction from north to south when it turns from positive to negative and vice versa.

The identification of turning points is a significant simplification of the problem in our robot thought experiment–we only need to know if the robot's plan is to head north or south.

Our Trend Indicator indicates a change from north to south by changing from positive to negative. It makes this transition about 25 days after the robot's first planned turning point. As it begins to detect the robot's second change of direction it turns from negative to positive again after the robot changes direction.

The second time the robot turns south its planned path is south-south-east–a more abrupt change in direction. The Trend Indicator observes this and turns negative closer to the peak of the noisy trajectory–only 13 days after the planned change of direction.

The Importance of Multiple Time Scales

Figure 3 shows two additional trend indicators– one Medium Term and one Long Term. In financial applications these typically use approximately 1 year and 1.5 years of daily data.

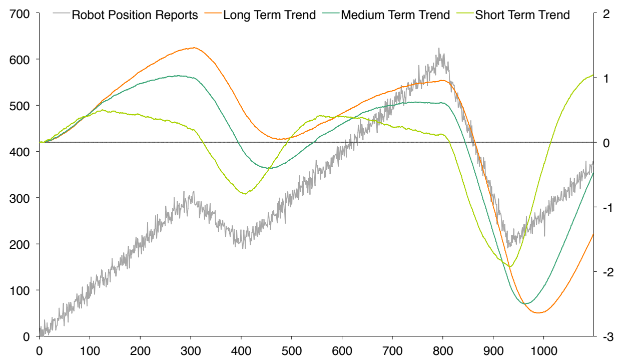

Figure 3. The Omega Metrics® Long, Medium and Short Term Trend Indicators (right hand scale) calculated from the time series of position updates.

These additional time scales help to differentiate between major and minor changes in direction. In the case of the robot, the Short and Medium Term Indicators both pick up the first change in direction however it is not long-lived enough to register with the Long Term Indicator. The second, much longer transition to a southerly motion is picked up by all three Indicators.

The Short Term Trend is the first to see a downturn—shortly after what turned out in retrospect to have been the actual turning points in the robot trajectory. In the case of a major change in direction it is followed by the two slower, smoother indicators. Using these multiple time scales produces a cascade of warnings.

The Trends Corresponding to the Planned Trajectory

Figure 4 shows the Trend Indicators obtained from the time series of planned trajectory points. The obvious similarity between Figure 3 and Figure 4 illustrates the effectiveness of treating noisy data as though it were guided by smooth underlying 'virtual' trajectory. The Trend Indicators in the two cases are so close to identical that they are indistinguishable at the resolution of our graphs.

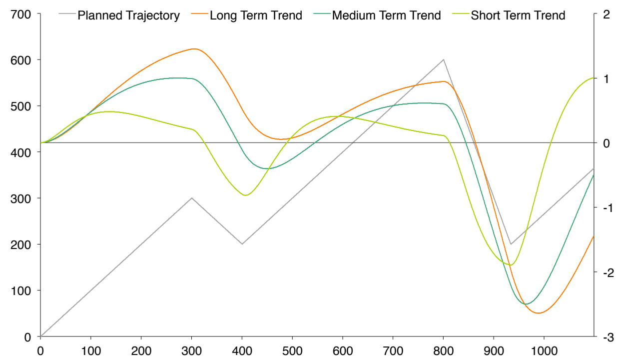

Figure 4. The Omega Metrics® Long, Medium and Short Term Trend Indicators (right hand scale) calculated from the time series of the straight line segments forming the planned trajectory. The Indicators calculated from the noisy position data are almost identical to those from the deterministic path.

In financial applications where there's no underlying smooth trajectory the same Trend Indicators respond as if there were, identifying the transitions in the market 'momentum' from up and down and back again.

Trend Indicators for the Nasdaq 100 Index

We measure the effectiveness of the Trend Indicators by comparing the annualised 'buy and hold' return in the index with the annualised return over periods delineated by the signs of the Trend Indicators.

Over the past three decades, our Trend Indicators have been highly predictive of profitable and unprofitable periods.

(cont.)

Trend Indicators for the Nasdaq 100 Index

During that time the annualised return on the Nasdaq 100 Index was under 10%. But when all three Indicators were positive this rose to over 24%.

While the Short Term Indicator was negative the annualised return dropped to -3%.

When all three Indicators were negative it fell all the way to -8%.

Figure 5 shows the most recent instance of the cascade of warnings for the Nasdaq 100 Index. The Long Term Trend Indicator followed the Short and Medium Indicators and turned negative on 29 December 2015 when the Index closed at 4,691. Following this the Index dropped almost 16% to its 11 February 2016 low of 3,962.

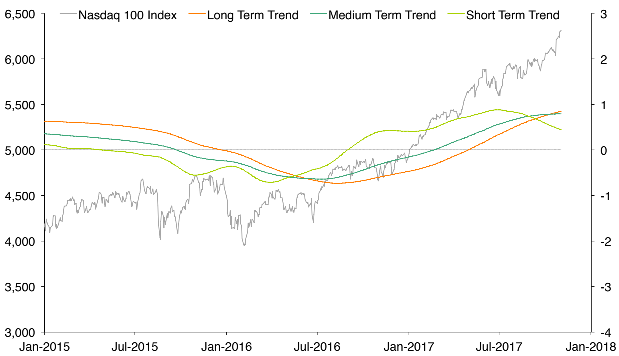

Figure 5. The Omega Metrics® Long, Medium and Short Term Trend Indicators (right hand scale) calculated from the time series of daily Nasdaq 100 Index levels. The last time that all three Indicators turned negative the Index dropped by almost 16%.

Perhaps ominously, the Short Term Trend has again begun to turn down after peaking in June 2017.

Appendix

The robot in our thought experiment moves in regular steps 1 meter to the east and then north or south depending on both its planned trajectory and a random draw from a normal distribution with mean 0 meters and standard deviation 12 meters.

The regular eastward movement functions as a clock so that we might as well think of the plot of the observed positions as a time series where the northern component of the position is the output at each time interval.

The planned trajectory has been chosen so that the peaks and troughs in the plotted position occur at frequencies in days similar to those observed in financial markets—which our generic Short Term, Medium Term and Long Term Trend Indicators are designed to deal with.

The planned trajectory segments are:
- Segment 1 north east.
- Segment 2 south east
- Segment 3 north east
- Segment 4 south south east
- Segment 5 north east.

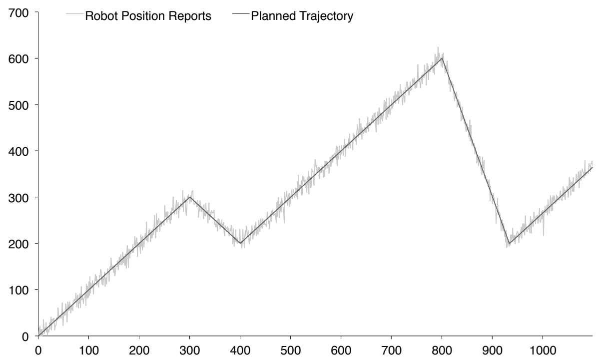

Figure A1. The Planned Trajectory formed by straight line paths and the Robot Position Reports produced by random deviations from the plan.

About the Authors

William F. Shadwick is a founding partner and the Managing Director of Omega Analysis Limited. During his previous career in mathematics he was responsible for establishing the Fields Institute for Research in Mathematical Sciences and worked in many prestigious institutions, including the Institute for Advanced Study, Princeton, the Mathematical Sciences Research Institute, Berkeley, IMPA, Brazil and the NASA Ames Research Center.

Dr. Ana Cascon is a founding partner of Omega Analysis Limited. She was a tenured professor in the Applied Mathematics Department of the Federal University Fluminense, Rio de Janeiro, Brazil, and is a first rate mathematician who has held research and teaching positions in leading centres in France, Canada and Brazil. She is an expert in the use of symbolic computation techniques for mathematical modelling.

Shadwick and Cascon have jointly pioneered a fundamentally new approach to the study of probability and statistics which continues to generate powerful new tools for performance measurement, risk management and trading strategies. Cascon and Shadwick were the recipients of the 2007 Journalism Award and the 2010 Edward D. Baker III Journal Award of the Investment Management Consultant's Association for their published research on risk and performance measurement. In 2010, Shadwick was the University of Hawaii Mathematics Department's Distinguished Lecturer.

In October 2016, Omega Analysis came second, Highly Commended for 'Best Economic Research' in Investment Week's inaugural Research Awards.

In the 2017 Research Awards, Omega Analysis was shortlisted for Best Research Service and Best Research Report.

Omega Analysis

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