Introduction to *QuanTek*

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Contents

QuanTek is a **stock** (and also **commodities**) trading program designed for short-term traders and long-term investors. The main purpose of ***QuanTek*** is to find **correlation** in the stock price data and then design **Technical Indicators** and **Trading Rules** to take advantage of this **correlation**. In this way ***QuanTek*** makes use of the most state-of-the-art principles of **Econometrics**, as well as **Digital Signal Processing**, available at the present time. ***QuanTek*** also incorporates a **portfolio optimization** routine, to compute the **optimal portfolio** to yield **maximum returns** with **minimum risk**.

QuanTek has many state-of-the-art features, but the most important feature of ***QuanTek*** is the capability to design a set of custom **Technical Indicators**, and then use the built-in *correlation tests* to actually test their effectiveness, by measuring the **correlation** of these

indicators with *future returns*. These indicators are adjusted for maximum correlation with the future returns, over a period of (normally) 1024 days, and then **Trading Rules** are derived from these indicators. The **Technical Indicators**, in turn, rely on the **Price Projection**, which uses a custom **Linear Prediction** filter to make an *estimate* of future returns based on the **correlation** present in the past returns (and other data). Also used in the construction of the **Technical Indicators** is a state-of-the-art **Savitzky-Golay** smoothing filter, which is a modern version of the familiar moving average smoothing. This **Savitzky-Golay** smoothing filter has the advantage that it is *acausal*, so there is no time delay as in the conventional moving average. (This requires, of course, that it be used in conjunction with the **Linear Prediction** filter.) In this way it is easier to keep all the **Technical Indicators** in *phase*, which is an important feature of ***QuanTek***. You can adjust the *type* of digital smoothing, the *time scale*, and the *phase*, to arrive at a wide variety of indicators. You adjust the parameters for maximum *correlation* with one-day future returns, in order to assure the effectiveness of each indicator. (This only assumes that the *correlation* itself is *persistent*, unlike the traditional assumption that the *trend* is *persistent*. The validity of this assumption is verified by means of the **Diagnostic Test**, a *back-testing* routine for testing a variety of realistic trading scenarios.) ***QuanTek*** also has a variety of **statistical tests**, which can be used to evaluate the state of each stock, as well as the overall market conditions.

At this point we would like to warn you that ***QuanTek*** is merely a *tool* to help you time your trades for **increased returns** with **reduced risk**. It is still of utmost importance for each investor or trader to *use his or her own judgment* in all investment or trading decisions. The ultimate responsibility for wise investing or trading rests with you, the investor or trader. The ***QuanTek*** program can help you time your trades more accurately, but ***QuanTek*** cannot supply all the information you need to make fully informed trading decisions. You should take into account the overall condition of the economy, as well as the health of various business sectors and the fundamental condition of each company you want to invest in. It is only after these factors have been considered that you should engage in long-term investing or short-term trading in any particular company's stock. (This is also why ***QuanTek*** does not tell you *which* stocks to buy!) Even after this, you should always let your own judgment be the final criterion for each and every investment or trading decision. It is always unsafe to blindly trust the advice of any financial guru, broker, investment newsletter writer, as well as any software product, without subjecting it to your own critical examination and *making the final judgment yourself*!

Stochastic Processes and Filtering

In the usual approach to **Technical Analysis** [Edwards & Magee (1991)], one looks for certain patterns in the past stock prices, which indicate potential buy/sell points. This is because these patterns in past prices are thought to be *correlated* with future up-trends or down-trends, either a change in trend from up to down or down to up, or a continuation of the current trend. These standard technical indicators are probably so well known by now that they are largely ineffective, since everyone follows them, and in addition they were more effective 50 to 80 years ago, when the markets were much smaller and much less efficient than they are now.

The ***QuanTek*** program works a little differently from the usual **Technical Analysis** program. ***QuanTek*** makes use of the state-of-the-art techniques of **Signal Processing** to construct new types of **Technical Indicators**. These technical indicators are tested for **correlation** with future returns, and adjusted for the optimum correlation. Then a set of **Trading Rules** is constructed directly from these indicators. However, these technical indicators are constructed using the same basic principles as the standard indicators, but utilizing modern computer routines which would have been impossibly difficult to use by hand in the old days.

Stochastic Processes

Financial returns data constitute what is known as a **stochastic process**. The simplest type of stochastic process is the familiar **Random Walk**. It was first postulated over a century ago that stock price returns follow a Random Walk. It is still hotly debated even now whether this is in fact the case. Many people, when performing a statistical analysis of stock data, are unable to discern any statistically significant difference between stock returns series and a Random Walk. My position is that the stock returns are *not even* a Random Walk. A **RandomWalk** (with drift) is a **stationary stochastic process**, meaning that the statistical properties do not change with time. In particular, if the returns series were a Random Walk, then it would have a constant *drift velocity* or *secular trend*. In that case, the only sensible investment strategy would be *buy & hold*, to take advantage of this secular trend, which would always be constant. This is really quite a strong prediction of future price action! However, this is too good to be true, and evidently the constancy of this secular trend is too much to ask. Instead, it appears that price returns data constitute a **non-stationary stochastic process**. This means that the statistical properties vary with time, including the drift velocity or trend, and the correlation structure. So in this case, the optimal strategy is one of *active trading*. The purpose of the ***QuanTek*** program is to try to determine the optimum **Trading Rules** to take best advantage of this non-stationary correlation structure.

QuanTek has the capability to construct a variety of different **technical indicators** and measure the **correlation** between these and the *future returns*. The typical length of the (daily) data set used is $N = 1024$ days, or about four years. This means that there is a statistical uncertainty in the measurement of the correlation of about $1/\sqrt{N}$ or 3.125%. However, even a correlation of this magnitude could give a very nice annual gain if it were real, depending on the average daily volatility of the price returns. So this is the quandary: Small correlations can yield substantial profits from short-term trading, but these small correlations are buried in the stochastic noise and are of the same order of magnitude as the noise. This is the reason why researchers in the past have not been able to discern any (statistically significant) difference between stock returns data and random noise. Furthermore, the financial time series should be taken as a **non-stationary stochastic process**, so the correlation structure will be time dependent. So the problem is how to extract useful non-stationary correlations from the stochastic noise and convert this correlation into profitable trading rules. That is the problem that the ***QuanTek*** program addresses. The technique is to model the presumed correlations by means of an

Adaptive Linear Prediction filter, then to use this filter to make a **Price Projection** and derive **Trading Rules**.

It should be mentioned that in the case of stationary processes, the *law of large numbers* is used to prove theorems about the existence and uncertainty of correlations. The correlation is only defined in the limit as the size *N* of the data set goes to infinity. For a non-stationary process we do not have this luxury. In fact, one major problem with financial time series is that the actual amount of data is rather sparse, so the statistical uncertainties are always large. If the correlation changes over an interval of *N* days, then the statistical uncertainty in the correlation will be $1/\sqrt{N}$ and will never improve beyond that, no matter how long the data set is. So how can we ever prove the existence of correlation and the effectiveness of **Trading Rules**? Instead of the limit $N \to \infty$ which is usually used in the theory of stationary stochastic processes, we can in the present case substitute an average over a portfolio of stocks. The **Adaptive Linear Prediction** filter is applied to the returns series of each individual stock, and it yields **Trading Rules** for that stock that give a certain return per year. This return per year for an individual stock may be substantial, but the standard deviation of the return will also be substantial and will be of the same order of magnitude. However, if we keep applying the **adaptive filter** to the stock over a long period of time, the returns should be proportional to time *N*, while the standard deviation of returns only increases like $\sqrt{N}$. So eventually after a period of time, the average returns should become much greater than the uncertainty in returns. We can likewise reduce the standard deviation, relative to the returns, still further by computing the **Trading Rules** for an entire **portfolio** of stocks. The **return** for the portfolio divided by the **standard deviation** of return should decrease like $1/\sqrt{M}$ for a portfolio of *M* stocks (assuming the stocks are uncorrelated). More generally, it is given in terms of the variance-covariance matrix for the portfolio. This is where the **Portfolio Optimization** routine in ***QuanTek*** comes in. The **return** for the whole portfolio is **maximized** while the **risk**, or **standard deviation** of returns, is **minimized**, subject to the degree of **risk tolerance** that you select. It is only by examining the whole portfolio return over a period of years that the effectiveness of the **Linear Prediction filter** and **Trading Rules** can be evaluated.

Linear Prediction Filter

The ***QuanTek*** program uses a custom **Linear Prediction** filter which is **adaptive**, meaning that the filter measures the correlation each trading day over a period of the past 1024 days (from that day) and adapts the filter coefficients to the correlation it measures in this time interval. (In a future version of ***QuanTek*** we plan to upgrade this filter to a custom-designed **Wavelet filter**. This filter will use a long time period to measure the low-frequency correlation, but a short time period to measure the high-frequency correlation. This should give a better measure of correlation for the short time period correlations.)

The way this works, in a nutshell, is as follows: It is a well-known theorem, the **Wiener-Khinchin Theorem** [NR (1992)], that the **power spectrum** of a stationary stochastic process is the **Fourier Transform** of the **autocorrelation**. (We take the time series to be

stationary over the 1024 day period, as an approximation.) Then, starting with the spectrum of the process, it is always possible to compute the corresponding autocorrelation sequence, and given this autocorrelation sequence, the **Linear Prediction** filter coefficients can then be computed. This is the approach that is taken in ***QuanTek***. The **spectrum** of the process is measured using the **Fast Fourier Transform** and displayed as a standard **Periodogram**. However, there is a catch. It turns out that, and this is also a theorem, that the *standard deviation* of the straight periodogram is 100%, so each Fourier component is totally uncertain. So instead of a smooth spectrum, you get a result that looks like random noise. In order to extract information from the spectrum, the periodogram must be *smoothed*. This is done in the ***QuanTek*** display of the **Periodogram**. You can choose a wide variety of time scales for smoothing. For the **Adaptive Linear Prediction** filter, again we begin with the (slightly smoothed) **Periodogram**. In this case, a different method of smoothing is used, in the form of Chebyshev polynomials (essentially a Fourier cosine series). The first *N* Chebyshev polynomials give what is called the ***N*'th order approximation** to the spectrum. Then you change the degree of smoothing by choosing the order of the approximation to use. The **spectrum** contains all the information about the **correlation** in the time series. If the **spectrum** is completely flat and horizontal, then there is no correlation and the time series is just "white noise", or a **Random Walk**. If the spectrum shows a peak at low frequencies, then this indicates **positive correlation** of returns or **trend persistence**. If, however, the spectrum shows a peak at high frequencies, then this indicates **negative correlation** of returns or **trend anti-persistence**. So, contrary to dogma, it is not always true that the *trend is persistent* (trending market). Sometimes there is a *return to the mean* mechanism at work (trading market). Once you have chosen the order of the approximation to the spectrum, the filter coefficients are computed. The purpose of this *N*'th order approximation is to try to eliminate stochastic noise and capture only the real correlation in the filter coefficients. Otherwise, the result is likely to be merely "fitting to the noise", which is a common problem.

Another aspect of the custom **Linear Prediction** filter is that it incorporates what we call a **Fractional Difference** filter. This is a filter for **fractionally integrated noise** processes or so-called **long memory processes** [Brockwell & Davis (1991)]. The **fractionally integrated noise** process is characterized by a parameter which we call the **fractional dimension** *d* which ranges from –0.5 to +0.5. The fractional dimensions in the range $0 < d < +0.5$ characterize the *long memory processes*, which exhibit long-term *trend persistence*. The fractional dimensions in the range $-0.5 < d < 0$ are sometimes called *intermediate memory processes* and exhibit short-term *anti-persistence*. The long-memory processes are sometimes attributed to *fractal statistics*. It is thought that stock data exhibit this type of long memory persistence [Peters (1991, 1994)].

Some, but not all, of the periodograms for stock data in ***QuanTek*** exhibit a spike at the lowest frequency, indicating this long-term persistence corresponding to a positive fractal dimension. Accordingly, provision is made in the custom **Linear Prediction** filter to accommodate a positive (or negative) fractional dimension. (Zero fractional dimension corresponds to an ordinary autoregressive process as used in the ordinary **Linear Prediction** filter.) The *N*-order smoothing more or less smooths out this low-frequency

spike, but then you can set the fractional dimension to any value you like, and it varies the low-frequency spectral response of the *N*-order smoothed filter accordingly. This parameter is saved for each individual stock, in the stock data file.

It should be mentioned that the **Linear Prediction** filter is, as the name implies, essentially linear in its operation. The filter parameters specify a linear filter, which is a **linear** function of the past returns. However, non-linear functions of the past data can easily be accommodated in this approach, merely by defining **Technical Indicators** which are non-linear functions of the data. Our approach, at present, is to utilize a set of any three **Technical Indicators** to define the **Trading Rules** indicator, and you can set the proportion of the three indicators manually. However, this approach can be generalized to compute the optimum mix of any number of **Technical Indicators**, including **non-linear** ones, thereby arriving at a more general **non-linear** model of the stock data. We intend to do this in a future version of the ***QuanTek*** program. In this way our **Technical Indicators** can more closely approximate those of traditional **Technical Analysis**, which if expressed as mathematical functions of past price data, would be highly **non-linear** functions of the data. In addition, one of the **Technical Indicators** can be a stock index of your choice. Computing the correlation of each stock with this index and incorporating the index in the **Trading Rules** is the essence of the **Capital Asset Pricing Model** (**CAPM**), which we also intend to incorporate in ***QuanTek***. It would also be straightforward to incorporate any other kind of fundamental or economic data such as earnings or interest rates, just as long as these data are available from the data provider.

Hybrid Filter Parameters Dialog

In the toolbar for the Main Graph display for each individual stock data file, you will find a button which opens the **Hybrid Filter Parameters** dialog box. This dialog box is used to set the parameters for the **Linear Prediction** filter for each individual stock. The computations of the future **Price Projection** required for the **Technical Indicators** can also be done from within this dialog box. (These can also be done by click *Calculate Data* on the toolbar.)

There are two displays in this dialog box. The top display is the **Periodogram** of the **Fourier spectrum** of the returns data (slightly smoothed), almost identical to the top display in the **Periodogram** dialog box (see the discussion of the **Periodogram** below). The bottom display is the result of the *N*'th order approximation to this **Periodogram**. The bottom display also shows the effect on the spectrum of including a non-zero **fractional dimension**. The **Filter Approximation** and **Fractional Dimension** are set in the list box or spin indicator, and the effect this has on the smoothed spectrum is immediately displayed in the bottom display. When you have decided on the filter parameters to use, click the Compute button, and the **Price Projections** will be computed using these parameters. (The **Price Projection** used in the Main Graph is that of the unsmoothed, $N = 512$ setting of the Filter Approximation, but using the Fractional Dimension that you set in this dialog box. This is updated when you exit from the dialog box.)

Also shown is an *estimate* of the *potential* gains from active trading, based on the **Kolmogorov-Smirnov** test. This is a standard statistical test, which estimates the deviation of the (slightly smoothed) spectrum from a purely random spectrum. The result of the test is expressed as a *Confidence Level*, which is a measure of the probability that the spectrum is non-random. This is one minus the *Significance Level*, which is the probability that the spectrum could result from random chance. The way the estimate of potential gains is derived is as follows: As mentioned before, the measured standard deviation of correlation due to random chance, of 1024 data points, is 3.125%, which is one standard deviation. One standard deviation corresponds to a *Confidence Level* of 68%, because there is a 32% chance that the correlation could reach or exceed this level by chance alone (*Significance Level*). Hence, we can estimate the correlation inherent in a spectrum, which deviates from a random spectrum, by equating the *Confidence Level* from the **Kolmogorov-Smirnov** test to the *Confidence Level* of the correlation, based on the Gaussian distribution. Given that one standard deviation of correlation is 3.125%, the actual amount of correlation corresponding to that *Confidence Level* is computed. Then the corresponding Simple Gain and Compound Gain (annualized) is computed, making use of the measured average volatility of returns. The result is displayed in the dialog box. This gives a rough estimate of the correlation that might be present in the spectrum, based on the shape of the spectrum itself and independent of the other correlation tests. (Note: This estimate is *not* a standard statistical estimate. It should be interpreted as a rough estimate only.)

Statistical Tests in *QuanTek*

At present the ***QuanTek*** program has three main sets of dialog boxes for performing statistical tests on the stock data. These tests are rather sophisticated, and somewhat complex. Here we will try to summarize them, and you can get more information from the article Correlations and Trading Rules in ***QuanTek***, the Help file, and from practicing using them.

When you first open the ***QuanTek*** program, you are presented with a dialog box that has three large icon buttons on it. These three buttons correspond to the statistical tests described below, so you can go directly to one of the three tests if you wish. The same three buttons are available on the toolbar of the Main Window, when no stock data files are open.

Correlation – Indicators

This dialog box opens in response to the middle button of the opening dialog box. When you click this button, you are taken to a dialog box, which contains a scatter graph displaying the correlation between a **technical indicator** and the **future returns**. You first choose a stock data file to work with, which you access from an Open File dialog. (These are the stock data files that you create and store on your hard drive.) Next, you open another dialog, called the **Technical Indicators** dialog, which enables you to create a custom technical indicator. You may also select the **Correlation Test** dialog, which displays the correlation as a function of **lead-time**, as a bar graph, along with some other information. (The **Technical Indicators** dialog is also available from the **Correlation**

Test dialog.) This display graphically shows the variation of the **correlation** with the **phase** of the technical indicator, enabling you to adjust the phase for maximum correlation.

Technical Indicators Dialog

The **technical indicators** are various kinds of **oscillators** formed from the past price history of the stock, using various types of smoothing. The main type of smoothing used is that obtained from a **Savitzky-Golay digital smoothing filter**. This is a type of smoothing filter, of which the most elementary example is the ordinary simple Moving Average, but it goes far beyond the simple MA. In fact, the simple MA is the "zero order" realization of this filter, but in ***QuanTek*** we use a fourth-order filter instead. For this reason, the filter exhibits almost no lag, unlike the simple (or exponential) MA. This SG filter can be used either as an *acausal* filter or as a *causal* filter. A third type of smoothing used in ***QuanTek*** is the ordinary **Exponential Moving Average**, which is also *causal* (like the simple MA). You can choose one of these three types of smoothing filters, with any one of a wide range of smoothing time scales. In addition, you can choose three types of indicators, which we call the **Relative Price**, **Velocity**, and **Acceleration**. The *Relative Price* is just the smoothed price data (relative to a longer time scale smoothing). The *Velocity* is the smoothed *first derivative* of the price data, or in the case of the Exp. MA it is the smoothing of the first difference of the prices (i.e., *returns*). Taking the derivatives (rates of change, from Calculus) of the price data is easy using the **Savitzky-Golay** smoothing filter. Finally, the *Acceleration* is the smoothed *second derivative* of the price data, or the second difference in the case of the Exp. MA. You can choose one time scale (and lead time) of smoothing, or the difference between any two time scales (and lead times) of smoothing to form your technical indicator. From all these choices, a tremendous variety of different types of oscillators may be formed. (In future versions of ***QuanTek***, we plan to include even more types of technical indicators, including data such as volume, interest rates, market indexes, and so on. We also plan to incorporate various *nonlinear* functions of the data, to take into account possible *higher-order correlation* in the data. Computing the ordinary correlation of nonlinear functions of the data is an alternative to other (non-parametric) techniques such as the *neural network*. Here we are using a parametric approach.)

Correlation Test Dialog

After selecting a **technical indicator**, you may select the **Correlation Test**, which displays the **correlation** between the **technical indicator** and the *future returns*, as a function of the *lead time* of the indicator. In this dialog, you can shift the phase, or **lead time**, of the **technical indicator** so as to achieve a peak **correlation**. For the value of the correlation which falls under the "ZERO" mark, the dialog displays the numerical value of the correlation, the volatility of the returns, and then computes and displays a *theoretical return* which would result from an idealized trading strategy, with this value of the correlation. From this you can get an idea of the potential returns that can be realized if this indicated correlation is real. Also shown is a band indicating the range or *standard error* of the measured correlation, and hence of the returns to be expected from short-term trading. It turns out that, while some very healthy returns are theoretically possible, the *range* of possible outcomes is also very wide. So it is important to pursue

any short-term trading strategy within the context of an overall portfolio strategy, to reduce the level of *risk.*

Trading Rules

The **Correlation Test** dialog, also containing the **Technical Indicators** dialog, is also available on the **Main Graph** toolbar when each stock data file is opened (as well as within the **Correlation – Indicators** dialog). In this context, you may design a set of three **custom Momentum indicators** for each stock. You can test these for **correlation**, and design them so they are optimized for that particular stock. The parameters for these indicators are saved with the stock data file. Then, these three *Momentum indicators* form the basis for the **Trading Rules** for that stock. You use a separate dialog box (**Trading Rules Parameters** dialog) with three slider bars, to form a sum of these three **Momentum** indicators in any proportion you choose, to form the **Trading Rules** indicator. Then, this indicator is used as the basis for computing the **buy/sell points** for that stock, and the **Trading Rules**. In this way, the *buy/sell points* are derived directly from the three *Momentum indicators*, which have been chosen for maximum correlation with future returns. This provides a verifiable way of checking whether they are actually likely to work or not.

Diagnostic Test

Within each stock data file, there is a **back-testing** routine called the **Diagnostic Test**. This may be used to test the **Trading Rules** under a variety of simulated trading scenarios. At present there are six tests available. Each of these tests is for a 1-day time horizon only, so the position is varied each day based on the 1-day **Trading Rules**. The **Market Orders** test uses the **Trading Rules** indicator directly, varying the position each morning at the opening price to adjust it to the optimum (*N*-day smoothed) position. The **Limit Orders** test uses the **Trading Rules** indicator in conjunction with the **buy/sell signals** to change the position only if the buy/sell signal is "activated". The **Day Trading-Fixed** test uses the output of the **Fractional Difference** filter in simulated trading where each position is established at the close price for the day and held until the next close. The **Day Trading-Float** test also uses the output of the **Fractional Difference** filter, except now the position is established at the next morning's opening price, and the position is varied according to this opening price. The **Random Numbers** test uses the output of a random number generator for the trading rules, and the **Constant Equity** test keeps the total equity invested in the stock constant (rounded down to the nearest round lot). Even these last two tests show a consistent profit, because due to the *return to the mean* mechanism, when the equity in the stock is held constant, this implies that shares are bought when the price is low and sold when the price is high. So this strategy is actually similar to the "Dollar Cost Averaging" method. In summary, the **Diagnostic Test** provides a realistic simulation of the **Trading Rules** in a variety of scenarios, and an independent verification of the theoretical gain from **correlation** computed in the **Correlation Test** dialog.

Correlation – Stocks

The **Correlation – Stocks dialog** is also available from the opening dialog, or from the toolbar of the Main Window. This dialog box also displays a scatter graph of

correlation, but this time between the **returns** of any two stocks that you select. These can be different stocks, or the same stock (in which case the **correlation** is the **autocorrelation**). You can view the correlation for each setting of the **time lag** between the two returns. There is also a separate display (bar graph) of the correlation as a function of time lag, one for positive lag and one for negative lag. In the case of autocorrelation, these form a standard bar graph of autocorrelation as a function of lag time. These correlation and autocorrelation graphs are useful for selecting compatible securities for your portfolio, for the sake of diversification, as well as general studies of the correlation structure of price returns.

Periodogram

This is a third dialog box that is available from the opening dialog, or from the toolbar of the Main Window. This dialog contains a standard statistical test for computing the **spectrum** of the time series of price returns. For more information, see the article Correlations and Trading Rules in ***QuanTek***. The spectrum is computed using both the **Periodogram** method and the **Maximum Entropy** method. (The former is based on the **Fourier Transform**, and the latter is based on the **Linear Prediction** filter.) The results are also compared to the spectrum of a purely random Gaussian process. Unfortunately, from this test there is no outstanding deviation of the spectrum from that of a Gaussian process, although many peaks and valleys are seen for both the stock price returns and the Gaussian process. The Periodogram is also used directly in the computation of the **Linear Prediction** filter coefficients, after suitable smoothing.

Graphs and Displays in *QuanTek*

QuanTek has a variety of graphs and displays. There is a **Main Graph**, which displays all the stock price data in a scrollable display. The **Main Graph** comes in four different **scales**, each of which displays a different aspect of the data. Also noteworthy is the **Price Projection** on the **Main Graph**, which shows the output of the **Price Projection** filter. This filter attempts to estimate the future price action, based upon any **correlation** in the past price returns that might exist.

In addition, there are three different **Splitter Windows**, each of which has three panes, making a total of nine displays. These display various **technical indicators**. Three of these technical indicators are the **Momentum Indicators,** which you design yourself using the **Technical Indicators** dialog box. A weighted sum of these three indicators is displayed as the **Trading Rules Indicator**, from which the **buy/sell signals** and **buy/sell points** are derived and upon which the **Trading Rules** are based. These nine splitter windows, along with the **Main Graph**, are designed for the purpose of displaying a clear set of **buy/sell signals and points** and other indicators for short-term trading, and long-term investing.

Main Graph

The **Main Graph** is designed to give a panoramic view of the entire data set, and is easy to interpret and easily scrollable. The vertical axis moves automatically to keep the display centered. There are four **scales** of the graph, each of which display different

information. For more information, please see the article How to Use the ***QuanTek*** Trading Rules. The display is available in either a **black** or **white** background. There is also a **tooltip**, which lists the **date** and **price** at any point where the mouse cursor is located. The **Main Graph** also displays **buy/sell signals**, **buy/sell points**, and a **long-term smoothing curve**, **short-term smoothing curve**, **long-term trend line**, and the highest scale is a **Candlestick chart**. In connection with the long-term smoothing curves and trend lines, a set of **Bollinger Bands** are displayed, corresponding to one- and two-standard deviations of the average absolute deviation of the prices from the long-term curves. The **relative volume** is also displayed along the bottom of the graph. Also, the **Price Projection** is displayed in blue, after the most recent past data on the graph. This display shows the output of the **Price Projection** filter. There is an error bar for each future projected price, to display an approximate one-standard-deviation range for the future price. This range is approximately proportional to $\sqrt{n}$, where *n* is the number of days in the future for the projected price. (This corresponds to the standard deviation of the *Random Walk* process.)

Splitter Windows

There are three splitter windows, each with three panes. For more information, please see the article How to Use the ***QuanTek*** Trading Rules. These three splitter windows display a compatible set of nine technical indicators, showing **buy/sell points** as vertical green/red lines in each window. The *present time* is displayed as a vertical yellow line. To the *past* of this line, the past data are smoothed, and **buy/sell points** are displayed *with the benefit of hindsight*. To the *future* of this line, the future *price projection* is displayed (based on *past* data), and future estimated **buy/sell points** are also shown. This *price projection* is based on the **Price Projection** filter. The whole data set, past data plus future projection, is smoothed using the **Savitzky-Golay** smoothing filter.

Harmonic Oscillator Splitter Window

The panes of this splitter window are called **Relative Price**, **Velocity**, and **Acceleration**. These three indicators display a smoothed difference of prices between a short-term and longer-term smoothing, a smoothed *first derivative* or *returns*, and a smoothed *second derivative* or rate of change of returns, respectively. Using **acausal SG** smoothing, so that there is no lag or phase shift, the **buy/sell points** should line up with the minima/maxima (**min/max**) of the **Relative Price**, the positive/negative zero-crossing (**Z+/Z–**) of the **Velocity**, and the maxima/minima (**max/min**) of the **Acceleration**, respectively. Using **causal SG** smoothing, there may be some phase shift, and using **Exponential MA** smoothing, there is a certain time lag in these **buy/sell points**. This splitter window provides confirmation for the **buy/sell points** derived from the **Momentum Indicators** in the **Momentum Indicators** splitter window.

Momentum Indicators Splitter Window

The three panes of this splitter window contain the **Momentum 0**, **Momentum 1**, and **Momentum 2** technical indicators. These three technical indicators are defined by you using the **Technical Indicators** dialog box, in either the **Correlation Test** dialog or the **Correlations – Indicators** dialog. You find technical indicators, which show a positive correlation with *future returns*, and adjust the **phase** or **lead time** of the indicators so that

the measured correlation is maximum. These indicators are then displayed in this splitter window, and the peaks and valleys of all three indicators should (approximately) line up. The **buy points** should line up with the **positive zero crossing** of the indicators, and the **sell points** should line up with the **negative zero crossing**. The **Momentum Indicators** are supposed to represent an *estimate* of the daily returns, and may be thought of as a surrogate for the **Velocity** indicator. Hence the optimum **Trading Rules** may be taken to be proportional to the value of the **Momentum Indicators** at any point in time.

Trading Rules Splitter Window

Using the **Trading Rules Parameters** dialog for each stock, you form a weighted sum of the three **Momentum Indicators** to form the **Trading Rules Indicator**. Adjusting the three slider bars corresponding to the three **Momentum Indicators** forms the weighted sum. Then this **Trading Rules Indicator** is displayed in the bottom pane of the **Trading Rules** splitter window. The **buy/sell signals** and **buy/sell points** are then derived from this indicator. The **buy/sell signals** are an optimal range of buy and sell limit orders. You can set the level and range of these buy/sell signals using the **Threshold** and **Range** slider bars in the **Trading and Portfolio Parameters** dialog. Please see the article How to Use the ***QuanTek*** Trading Rules for more details. The **buy points** line up with the **positive zero crossings** of the **Trading Rules Indicator**, and the **sell points** line up with the **negative zero crossings** of this indicator. Since you have chosen the three **Momentum Indicators** for maximum correlation with *future returns*, the **Trading Rules** derived from the **Trading Rules Indicator** have the best possible chance of *actually working*.

One of the two other panes of this splitter window contains a smoothed graph of **Volatility**, which is the absolute value of the daily returns from one close to the next. The other pane has a display of the output of the **Fractional Difference** filter, for a **negative fractional difference parameter**. This graph consists of a number computed separately for each day in the past, which represents the expected one-day return for the next day, given the past data up to that day. This one graph is the only one that is not smoothed. Thus it is a little different from the other splitter window graphs. This graph shows the **trading rules for day trading**, because it is the expected one-day return for the next trading day. These **day trading rules** are incorporated into the **Day Trades dialog**, which you can see from anywhere in the ***QuanTek*** program just by right-clicking the mouse.

Day Trades Dialog

This is a *modeless* dialog box, which can be seen from anywhere in the ***QuanTek*** program just by right-clicking the mouse. It displays all the most important trading information for the whole portfolio of stocks together in one place, to make it easier to see upcoming trades at a glance. In the main list box of this dialog, each stock is displayed on one line. (You can open each stock data file by double clicking on this line.) The line of information starts with the **stock symbol** and **number of shares** currently held. Then the output from the **Portfolio Optimization** routine is shown,

which consists of the **recommended number of shares** in the **core portfolio** and the **percentage of the total equity** in the **core portfolio** for each security. Then the **expected annualized return** is shown, based on the **Price Projection** and **smoothing** on the **Main Graph**. Next is shown a **buy/sell/hold recommendation** for the upcoming day, and a **price**. The **buy/sell recommendation** corresponds to an upcoming **buy/sell signal**, which can also be viewed on **scale 4** of the **Main Graph** for each stock. The price is the **recommended price** for the **buy/sell signal**. This recommended price is displaced below/above the *N*-day smoothed price for the stock, by an amount determined by the **Threshold** setting in the **Trading and Portfolio Parameters** dialog. (Whether or not there is a buy/sell signal, given the level of the **Trading Rules** indicator, is determined from the **Range** setting in this dialog.) If there is no buy or sell signal, then the recommendation is for a **hold**, and the price listed is just the upcoming *N*-day smoothed price (estimated). The last number displayed is the **optimum *N*-day trading position** for the next day, for that stock, where *N* is the trading time scale. This is just the (relative) value of the **Trading Rules** indicator, as explained in the article How to Use the ***QuanTek*** Trading Rules.

On the right-hand side of the **Day Trades** dialog, there is a list box containing a column of prices on the left and a column of percentages on the right. In the center (vertically) of the list box, corresponding to ZERO percent, the price listed is the **estimated closing price for the next trading day**. This estimate is based on the estimate of the next-day return from the **Fractional Difference** filter, with a *negative* **fractional dimension** parameter. This list box can be used by day-traders, in conjunction with the **Intra-day update**. By clicking on one of the prices in the list box (representing the current intra-day price), it is brought to the center, and then the *percentage price difference between that price and the estimated closing price* can be read from the right-hand column. Each trader can then base his/her day-trading position on this percentage price difference. This is the most versatile way we could think of to accommodate a wide range of **day-trading strategies**.

Other Features

These are the most important features of ***QuanTek***. There are many other features as well. The actual prices are displayed in list form in the **Stock Data** window. The list of stocks, indexes, and other types of files in the currently active **portfolio** are shown to the left side of the Main Window in a list box. Double clicking on any one of these entries is a quick way to open that data file. There is also a **Portfolio Report** that you can view and save as a text file. There are several other dialog boxes to perform various functions. All of the features of ***QuanTek*** are described in much greater detail in the **Help file**.

References

Bouchaud, Jean-Philippe & Potters, Marc
Theory of Financial Risks: From Statistical Physics to Risk Management, Cambridge University Press (2000)

Brockwell, Peter J. & Davis, Richard A.

Time Series: Theopry and Methods, 2nd ed., Springer (1991)

Colby, R. & Meyers, T. Encyclopedia of Technical Market Indicators, McGraw-Hill (1988)

Edwards, Robert D. & Magee, John Technical Analysis of Stock Trends, John Magee Inc. (1992)

Johnson, M. The Random Walk and Beyond, John Wiley & Sons (1988)

Malkiel, Burton G. A Random Walk Down Wall Street, W. W. Norton & Co. (1999)

Mantegna, Rosario N. & Stanley, Eugene H. An Introduction to Econophysics: Correlations and Complexity in Finance, Cambridge University Press (2000)

Natenberg, S. Option Volatility & Pricing, McGraw-Hill (1994)

Peters, E. "Fractal Structure in the Capital Markets", *Financial Analysts Journal*, July/August 1989

Peters, E. Chaos and Order in the Capital Markets, New York: John Wiley & Sons (1991)

Peters, E. Fractal Market Analysis, New York: John Wiley & Sons (1994)

Press, William H., Vettering, William T., Teukolsky, Saul A., & Flannery, Brian P., Numerical Recipes in C, 2nd ed. [**NR**], Cambridge University Press (1992)

Sharpe, W.F.; Alexander, G.J.; Bailey, J.V. Investments, 5th ed., Prentice Hall (1995)

Sherry, Clifford J. The Mathematics of Technical Analysis, Probus Publishing Co. (1992)

Vaga, T. "The Coherent Market Hypothesis", *Financial Analysts Journal*, December/January 1991

Vaga, T. Profiting From Chaos, McGraw-Hill (1994)