METHOD AND SYSTEM FOR PRICING FINANCIAL DERIVATIVES

FIELD OF THE INVENTION

The invention relates generally to financial instruments and, more specifically, to methods and systems for pricing financial derivatives and for providing automatic trading capabilities.

BACKGROUND OF THE INVENTION

Pricing financial instruments, e.g., financial derivatives, is a complex art requiring substantial expertise and experience. Trading financial instruments, such as options, involves a sophisticated process of pricing typically performed by a trader.

The term "option" in the context of the present application is defined broadly as any financial instrument having option-like properties, e.g., any financial derivative including an option or an option-like component. This category of financial instruments may include any type of option or option-like financial instrument, relating to some underlying asset. Assets as used in this application include anything of value; tangible or non-tangible, financial or non-financial. For example, as used herein, options range from a simple Vanilla option on a single stock and up to complex convertible bonds whose convertibility depends on some key, e.g., the weather.

The price of an asset for immediate (e.g., 2 business days) delivery is called the spot price. For an asset sold in an option contract, the strike price is the agreed upon price at which the deal is executed if the option is exercised. For example, a foreign exchange (FX) option involves buying or selling an amount of one currency for an amount of another currency. The spot price is the current exchange rate between the two currencies on the open market. The strike price is the agreed upon exchange rate of the currency if the option is exercised.

To facilitate trading of options and other financial instruments, a trader prepares a bid price and offer price (also called ask price) for a certain option. The bid price is the price at which the trader is willing to purchase the option and the offer price is the price at which the trader is willing to sell the option. When another trader is interested in the option the first trader quotes both the bid and offer prices, not knowing whether the second trader is interested in selling or buying. The offer price is higher than the bid price and the difference between the offer and bid is referred to

as bid-offer spread.

A *call* option is an option to buy an asset at a certain price (i.e., a strike price) on a certain date. A *put* option is an option to sell an asset at a strike price on a certain date. At any time prior to the option expiration date, the holder of the option may determine whether or not to exercise the option, depending on the current exchange rate (spot) for that currency. If the spot (i.e., current market) price is lower than the strike price, the holder may choose not to exercise the call option and lose only the cost of the option itself. However, if the strike is lower than the spot, the holder may exercise the right to buy the currency at the strike price making a profit equal to the difference between the spot and the strike prices.

A forward rate is the future exchange rate of an asset at a given future day on which the exchange transaction is performed based on an option contract. The forward rate is calculated based on a current rate of the asset, a current interest rate prevailing in the market, expected dividends (for stocks), cost of carry (for commodities), and other parameters depending on the underlying asset of the option.

An *at-the-money* forward option (ATM) is an option whose strike is equal to the forward rate of the asset. In this application, at-the-money forward options are generically referred to as at-the-money options, as is the common terminology in the foreign exchange (FX) and other financial markets. An *in-the-money call* option is a call option whose strike is below the forward rate of the underlying asset, and an *in-the-money put* option is a put option whose strike is above the forward rate of the underlying asset. An *out-of--the-money call* option is a call option whose strike is above the forward rate of the underlying asset, and an *out-of-the-money put* option is a put option whose strike is below the forward rate of the underlying asset.

An exotic option, in the context of this application, is a generic name referring to any type of option other than a standard Vanilla option. While certain types of exotic options have been extensively and frequently traded over the years, and are still traded today, other types of exotic options had been used in the past but are no longer in use today. Currently, the most common exotic options include are "barrier" options, "binary" options, "digital" options, "partial barrier" options (also known as "window" options), "average" options and "quanto" options. Some exotic options can be described as a complex version of the standard (Vanilla) option. For example, barrier options are exotic options where the payoff depends on whether the underlying asset's price reaches a certain level, hereinafter referred to as "trigger", during a

certain period of time. The "pay off" of an option is defined as the cash realized by the holder of the option upon its expiration. There are generally two types of barrier options, namely, a knock-out option and a knock-in option. A knock-out option is an option that terminates if and when the spot reaches the trigger. A knock-in option comes into existence only when the underlying asset's price reaches the trigger. It is noted that the combined effect of a knock-out option with strike K and trigger B and a knock-in option with strike K and trigger B, both having the same expiration, is equivalent to a corresponding Vanilla option with strike K. Thus, knock-in options can be priced by pricing corresponding knock-out and vanilla options. Similarly, a one-touch option can be decomposed into two knock-in call options and two knock-in put options, a double one-touch option can be decomposed into two double knock-out options, and so on. It is appreciated that there are many other types of exotic options known in the art.

Certain types of options, e.g., Vanilla options, are commonly categorized as either European or American. A European option can be exercised only upon its expiration. An American option can be exercised at any time after purchase and before expiration. For example, an American Vanilla option has all the properties of the Vanilla option type described above, with the additional property that the owner can exercise the option at any time up to and including the option's expiration date. As is known in the art, the right to exercise an American option prior to expiration makes American options more expensive than corresponding European options. Generally in this application, the term "Vanilla" refers to a European style Vanilla option. European Vanilla options are the most commonly traded options; they are traded both on exchanges and over the counter (OTC). The much less common American Vanilla options are traded exclusively OTC, and are difficult to price.

U.S. Patent 5,557,517 ("the '517 patent") describes a method of pricing American Vanilla options for trading in a certain exchange. This patent describes a method of pricing Call and Put American Vanilla options, where the price of the option depends on a constant margin or commission required by the market maker. The method of the '517 patent ignores data that may affect the price of the option, except for the current price of the underlying asset and, thus, this method can lead to serious errors, for example, an absurd result of a negative option price. Clearly, this method does not emulate the way American style Vanilla options are priced in real markets.

The Black-Scholes model (developed in 1975) is a widely accepted method for valuing options. This model calculates a probability-based theoretical value (TV), which is commonly used as a starting point for approximating option prices. This model is based on a presumption that the change in the rate of the asset generally follows a Brownian motion, as is known in the art. Using such Brownian motion model, known also as a stochastic process, one may calculate the theoretical price of any type of financial derivative, either analytically, as is the case for the exotic options discussed above, or numerically. For example, it is common to calculate the theoretical price of complicated financial derivatives through simulation techniques, such as the Monte Carlo method, introduced by Boyle in 1977. Such techniques may be useful in calculating the theoretical value of an option, provided that the computer being used is sufficiently powerful to handle all the calculations involved. In the simulation method, the computer generates many propagation paths for the underlying asset, starting at the trade time and ending at the time of the option expiry. Each path is discrete and generally follows the Brownian motion probability, but may be generated as densely as necessary by reducing the time lapse between each move of the underlying asset. Thus, if the option is path-dependant, each path is followed and only the paths that satisfy the conditions of the option are taken into account. The end results of each such path are summarized and lead to the theoretical price of the derivative.

The original Black Scholes model is designed for calculating theoretical prices for Vanilla options. However, it should be understood that any reference in this application to the Black- Scholes model refers to use of any model known in the art for calculating theoretical prices of options, e.g., a Brownian motion model, as applied to any type of option, including exotic options. Furthermore, this application is general and independent of the way in which the theoretical value of the option is obtained. It can be derived analytically, numerically, using any kind of simulation method or any other technique available.

For example, U.S. patent 6,061,662 ("the '662 patent") describes a method of evaluating the theoretical price of an option using a Monte Carlo method based on historical data. The simulation method of the '662 patent uses stochastic historical data with a predetermined distribution function in order to evaluate the theoretical price of options. Examples is the '662 patent are used to illustrate that this method generates results which are very similar to those obtained by applying the Black-

Scholes model to Vanilla options. Unfortunately, methods based on historical data alone are not relevant for simulating financial markets, even for the purpose of theoretical valuation. For example, one of the most important parameters used for valuation of options is the volatility of the underlying asset, which is a measure for how the rate of the underlying asset fluctuates. It is well known that the financial markets use predicted, or "future", value for the volatility of the underlying assets, which often deviates dramatically from the historical data. In market terms, future volatility is often referred to as "implied volatility", and is differentiated from "historical volatility". For example, the implied volatility tends to be much higher than the historical volatility of the underlying asset before a major event, such as risk of war, or during and after a financial crisis.

It is appreciated by persons skilled in the art that the Black-Scholes model is a limited approximation that may yield results very far from real market prices and, thus, corrections to the Black-Scholes model must generally be added by traders. In the foreign exchange (FX) Vanilla market, for example, the market trades in volatility terms and the translation to option price is performed through use of the Black-Scholes formula. In fact, traders commonly refer to using the Black-Scholes model as "using the wrong volatility with the wrong model to get the right price".

In order to adjust the price, in the Vanilla market, traders use different volatilities for different strikes, i.e., instead of using one volatility per asset, a trader may use different volatility values for a given asset depending on the strike price. This adjustment is known as volatility "smile" adjustment. The origin of the term "smile", in this context, is in the foreign exchange market, where the volatility of a commodity becomes higher as the commodity's price moves further away from the ATM strike.

The phrase "market price of a derivative" is used herein to distinguish between the single value produced by some benchmark models, such as the Black-Scholes model, and the actual bid and offer prices traded in the real market. For example, in some options, the market bid side may be twice the Black-Scholes model price and the offer side may be three times the Black-Scholes model price.

Many exotic options are characterized by discontinuity of the payout and, therefore, a discontinuity in some of the risk parameters near the trigger(s). This discontinuity prevents an oversimplified model such as the Black-Scholes model from taking into account the difficulty in risk-managing the option. Furthermore, due to the peculiar profile of some exotic options, there may be significant transaction costs

associated with re-hedging some of the risk factors. Existing models, such as the Black-Scholes model, completely ignore such risk factors.

Many factors may be taken into account in calculating option prices and corrections. (Factor is used herein broadly as any quantifiable or computable value relating to the subject option.) Some of the notable factors are defined as follows:

Volatility ("Vol") is a measure of the fluctuation of the return realized on an asset. An indication of the level of the volatility can be obtained by the volatility history, i.e., the standard deviation of the return of the assets for a certain past period. However, the markets trade based on a volatility that reflects the market expectations of the standard deviation in the future. The volatility reflecting market expectations is called *implied volatility*. In order to buy/sell volatility one commonly trades Vanilla options. For example, in the foreign exchange market, the implied volatilities of ATM Vanilla options for many frequently used option dates and currency pairs are available to users in real-time, e.g., via screens such as REUTERS, Bloomberg, TELERATE, Cantor Fitzgerald, or directly from FX option brokers.

Volatility smile, as discussed above, relates to the behavior of the implied volatility with respect to the strike, i.e., the implied volatility as a function of the strike, where the implied volatility for the ATM strike is the given ATM volatility in the market. For example, for currency options, a plot of the implied volatility as a function of the strike shows a minimum in the vicinity of the ATM strike that looks like a smile. For equity options, as another example, the volatility plot tends to be monotonous.

Vega is the rate of change in the price of an option or other derivative in response to changes in volatility, i.e., the partial derivative of the option price with respect to the volatility.

Convexity is the second partial derivative of the price with respect to the volatility, i.e. the derivative of the Vega with respect to the volatility, denoted dVega/dVol.

Delta is the rate of change in the price of an option in response to changes in the price of the underlying asset; in other words, it is a partial derivative of the option price with respect to the spot. For example, a 25 delta call option is defined as follows: if against buying the option on one unit of the underlying asset, 0.25 unit of the underlying asset are sold, then for small changes in the underlying option, assuming all other factors are unchanged, the total change in the price of the option

and the 0.25 unit of the asset are null.

Intrinsic value (IV) for in-the-money knock-out/knock-in exotic options with strike K and trigger (or barrier) B, is defined as IV=|B-K|/B. In-the-money knock-out/knock-in options are also referred to as Reverse knock-out/knock-in options, respectively. For a call option, the intrinsic value is the greater of the excess of the asset price over the strike price and zero. In other words, the intrinsic value of in-the-money knock out options is the intrinsic value of a corresponding Vanilla at the barrier, and represents the level of payout discontinuity in the vicinity of the trigger.

25Δ Risk Reversal (RR) is the difference between the implied volatility of a call option and a put option with the same delta (in opposite directions). Traders in the currency options market generally use 25 delta RR, which is the difference between the implied volatility of a 25 delta call option and a 25 delta put option. Thus, 25 delta RR is calculated as follows:

25 delta RR = implied Vol (25 delta call) - implied Vol (25 delta put)

The 25 delta risk reversal is characterized by a slope of Vega with respect to spot but practically no convexity at the current spot. Therefore it is used to price the slope dVega/dspot.

25Δ Strangle is the average of the implied volatility of the call and the put, which usually have the same delta. For example:

25 delta strangle = 0.5 (implied Vol (25delta call) + implied Vol (25delta put))

The 25 delta strangle is characterized by practically no slope of Vega with respect to spot at the current spot, but a lot of convexity. Therefore it is used to price convexity. Since the at-the-money Vol is always known, it is more common to quote the butterfly in which one buys one unit of the strangle and sells 2 units of the ATM option. Like the strangle, butterfly is also quoted in volatility. For example:

25 delta butterfly = 0.5 (implied Vol (25delta call) + implied Vol (25delta put)) – ATM Vol

The reason it is more common to quote the butterfly is that butterfly provides a strategy with almost no Vega but significant convexity. Since butterfly and strangle are related through the ATM volatility, which is always known, they may be used interchangeably. The 25 delta put and the 25 delta call can be determined based on the 25 delta RR and the 25 delta strangle.

Gearing, also referred to as leverage, is the difference in price between the

exotic option with the barrier and a corresponding Vanilla option having the same strike. It should be noted that a Vanilla option is always more expensive than a corresponding exotic option.

Bid/offer spread is the difference between the bid price and the offer price of a financial derivative. In the case of options, the bid/offer spread is expressed either in terms of volatility or in terms of the price of the option. The bid/offer spread of a given option depends on the specific parameters of the option. In general, the more difficult it is to manage the risk of an option, the wider is the bid/offer spread for that option.

Typically traders try to calculate the price at which they would like to buy an option (i.e., the bid side) and the price at which they would like to sell the option (i.e., the offer side). Currently, there are no mathematical or computational methods for calculating bid/offer prices, and so traders typically rely on intuition, experiments involving changing the factors of an option to see how they affect the market price, and past experience, which is considered to be the most important tool of traders. Factors commonly relied upon by traders include convexity and RR which reflect intuition on how an option should be priced. One dilemma commonly faced by traders is how wide the bid/offer spread should be. Providing too wide a spread reduces the ability to compete in the options market and is considered unprofessional, yet too narrow a spread may result in losses to the trader. In determining what prices to provide, traders need to ensure that the bid/offer spread is appropriate. This is part of the pricing process, i.e., after the trader decides where to place the bid and offer prices, he/she needs to consider whether the resultant spread is appropriate. If the spread is not appropriate, the trader needs to change either or both of the bid and offer prices in order to show the appropriate spread.

SUMMARY OF THE INVENTION

Example embodiments of the present invention provide a method and a system for calculating option prices (e.g., bid and offer prices) and for providing automatic trading capabilities, e.g., via global computer network. Specifically, the method of the example embodiments enables automatic calculation of the bid and offer prices of options with accuracy comparable to that of an experienced trader. Thus the example embodiments also enable traders not only to correctly evaluate the price of the option, for example, the mid-market price of the option, but also to accurately determine the bid-offer spread of the option.

Further, since the computation of the bid and offer prices does not involve amorphous factors and/or trader intervention, investors may transact on the options based on the automatically generated bid and offer prices. By feeding the model of the example embodiments with real time market data, the model generates real time market prices for derivatives and, therefore, the model may automate the process of buying/selling derivatives.

In an example embodiment, the model may be used in conjunction with an online trading system whereby on-line transactions may be executed at the prices provided by the model. Liquidity providers, e.g., market makers and banks, may trade at the model prices instead of providing their own prices, i.e., they may sell options at the model generated offer price and buy at the model generated bid price avoiding any need for further calculations. Similarly, price-takers, e.g., hedgers, asset management groups, may execute deals automatically without prior automation of a bank on each transaction individually.

It is appreciated by persons skilled in the art that different types of asset markets are generally analogous in that they are controlled by analogous market conditions, e.g., forward rates, interest rates, stock dividends and costs of carry, and therefore, an option-pricing model which is suitable for one type of asset market is generally also adaptable to other types of markets, by appropriately interchanging the quantities used by the model with corresponding quantities of a different type of derivative. For example, to change the model from foreign exchange (FX) options to stock options, one would use the dividend rate of the stock in place of one of the interest rates used in the case of a pair of currencies.

Such adaptation may also be possible in cases where the analogy is not simple, for example, in weather derivatives. To adapt the model of the example embodiments to any type of option or option-like derivative, instead of simply replacing the quantities described below with corresponding quantities of a new type of derivative being computed, the model may be adapted by appropriately modifying its building blocks, which are described below, to accommodate the new type of derivative, and computing the price of the derivative based on the new building blocks. It should be appreciated that different option markets may share similar basic principle. Thus, although the example embodiments are described below in the context of the foreign exchange (FX) market, the model may be adapted to other option and option-like markets with appropriate changes, as will be apparent to those skilled in the art.

An example embodiment calculates bid and offer prices of an exotic option based on a corrected theoretical value (CTV) of the option and a bid/offer spread. The CTV may be computed based on a plurality of building blocks, as described below. For example, the CTV may be calculated based the theoretical value of the exotic option, a set of corrections, and a set of weights, each of which may be computed based on selection of the various details of the option including the spot, expiration date, class of the option (knock out, knock in, binary, European digital, etc.), strike (when applicable), barrier (s), forward rate to delivery, volatility for the expiration date, and interest rates of currencies. It is noted that a more complex exotic option may require additional details to define the option. A weight may be computed for each correction. Some or all of the weights may be time dependent. The corrected TV, also referred to herein as the adjusted mid-market price, may be computed as a function of the TV and the weighted corrections, or using any other suitable function of a plurality of building blocks that may reflect risks associated with the option.

To compute the bid/offer spread, a second set of weights may be computed corresponding to each correction, resulting in a different function of the building blocks, as described below. Some or all of the weights may be time dependent. The bid/offer spread may then be computed as a function of some base value and the weighted corrections, using the second set of respective weights. For example, the base value may be determined as the bid/offer spread of a Vanilla option corresponding to the subject exotic option. The weights applied to the corrections to determine the bid/offer spread are generally different from the weights applied to the corrections for the TV. In alternative example embodiments, the bid/offer spread may be computing using any other suitable function of a plurality of building blocks that may reflect risks associated with the option.

Finally, in computing the bid and offer prices, the model may include computation of volatility smile adjustment, for example, using a look-up table representing volatility smile adjustment in a predefined range. Such a look-up table may be generated by computing the volatility for each strike value and for each delta value in a predefined set. An analogous system and method may be used to compute the bid and offer prices for Vanilla options in addition to exotic options and other complex derivatives.

It should be appreciated that the benefit to financial markets from having an accurate model to price derivatives are enormous. First, the accurate model of the example embodiments may enable less experienced users of derivatives to price them accurately. Second, by virtue of having an accurate pricing model, the derivatives market is expected to become more liquid. Not being able to determine the correct price of derivatives creates strong dependency on market makers and causes users to refrain from using derivatives. Third, currently, many corporations and funds, for example, cannot establish credit lines with vis-á-vis each other and are required to deal only with banks. By having an accurate model for market prices, any two parties may deal with each other on a margin basis, even if they do not have mutual credit lines.

According to a first aspect of the present invention, there is provided a computer based data processing method comprising the steps of: receiving first input data corresponding to a plurality of parameters defining an option on an underlying asset; receiving second input data corresponding to a plurality of current market conditions relating to said underlying asset; computing a corrected theoretical value (TV) of said option based on at least part of said first and second input data; computing a bid/offer spread of said option based on at least part of said first and second input data; computing a bid price and/or an offer price of said option based on said corrected TV and said bid/offer spread; providing an output corresponding to the bid prize and/or the offer price of said option.

In some example embodiments, computing the bid price and/or the offer price includes computing a corrected theoretical value (CTV) of the option as a first function of at least some of the building blocks, computing a bid/offer spread of the option as a second function

of at least some of the building blocks, and computing the bid price and/or the offer price of the option based on the corrected TV and the bid/offer spread. The plurality of building blocks may include at least one building block selected from the group including convexity, risk reversal (RR), shift, gearing, Vega profile, and intrinsic value.

There may be a method for providing a bid price and/or an offer price of an option on an underlying asset, the method including receiving first input data corresponding to a plurality of parameters defining the option, receiving second input data corresponding to a plurality of current market conditions relating to the underlying asset, computing a

corrected theoretical value (CTV) of the option based on the first and second input data, computing a bid/offer spread of the option based on the first and second input data, computing a bid price and/or an offer price of the option based on the corrected TV and the bid/offer spread, and providing an output corresponding to the bid price and/or the offer price of the option.

According to a second aspect of the present invention, there is provided an apparatus for providing a bid price and/or an offer price of an option on an underlying asset comprising a server receiving first input data corresponding to a plurality of parameters defining said option and providing an output corresponding to a bid price and/or an offer price of said option, the server further receiving second input data corresponding to a plurality of current market conditions relating to said underlying asset; and a processor, associated with said server, which computes, based on at least part of said first and second input data, a corrected theoretical value (CTV) of said option and a bid/offer spread of said option, and which further computes, based on said CTV and bid/offer spread, the bid price and/or the offer price of said option.

According to a third aspect of the present invention, there is provided a computer based data processing method comprising the steps of: receiving first input data corresponding to a plurality of parameters defining an option on an underlying asset; receiving second input data corresponding to a plurality of current market conditions relating to said underlying asset; computing a plurality of building blocks based on at least part of said first and second input data, at least one of said building blocks being a function of a factor related to a risk associated with said option; computing a bid price and/or an offer price of said option as a function of at least some of said building blocks; and providing an output corresponding to the bid price and/or the offer price of said option.

In some example embodiments, in computing the bid price and/or offer price of the option, the processor computes a corrected theoretical value (CTV) of the option as a first function of at least some of the building blocks, a bid/offer spread of the option as a second function of at least some of the building blocks, wherein the processor computes the bid price and/or offer price of the option based on the corrected TV and the bid/offer spread. The plurality of building blocks may include at least one building block selected from the group including convexity, risk reversal (RR), shift, gearing, Vega profile, and intrinsic value.

According to a fourth aspect of the present invention, there is provided an apparatus for providing a bid price and/or an offer price of an option on an underlying asset, the apparatus comprising a server receiving first input data corresponding to a plurality of parameters defining said option and providing an output corresponding to a bid price and/or an offer price of said option, the server further receiving second input data corresponding to a plurality of current market conditions relating to said underlying asset; and a processor, associated with said server, which computes a plurality of building blocks based on said first and second input data, at least one of said building blocks being a function of at least one factor related to a risk associated with said option, and which further computes the bid price and/or the offer price of said option as a function of at least some of said building blocks.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description of a preferred embodiment of the invention, taken in conjunction with the accompanying drawings of which:

Figure 1 is a flow chart illustrating an overview of a method for pricing options in accordance with an embodiment of the present invention;

Figs. 2A-2D are sequential flow charts schematically illustrating an algorithm for calculating bid/offer prices of foreign exchange (FX) options in accordance with an embodiment of the present invention; and

Fig. 3 is a schematic block diagram illustrating a system for pricing options in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

A preferred embodiment of the present invention is described in the context of a model for calculating the market value (market price) of a foreign exchange (FX) exotic option. It should be appreciated, however, that models in accordance with the invention may be applied to other financial markets, and the invention is not limited to foreign exchange options or exotic options. One skilled in the art may apply the present invention to other options, e.g., stock options, or other option-like financial instruments, e.g., options on futures, or commodities, or non-asset instruments, such as options on weather, etc., with variation as may be necessary to adapt for factors unique to a given financial instrument.

In the embodiment described herein below, bid/offer prices are computed from a corrected theoretical value (TV) of an option and the bid/offer spread for that option. Computations for the corrected TV and bid/offer spread apply derivatives (partial derivatives up to second order) to factors readily available in the market. The factors include, for example, gearing (where the trigger is cancelled by setting it to zero, when the trigger is below the asset rate, or to infinity, when the trigger is above the asset rate) and the change in the profile of the Vega. Instead of trying to assess probabilities, the model presented herein enables assessment of the risk management cost of the option and of the compensation required by a trader in trading the option. In contrast to the Black-Scholes model, which is a probabilistic model, the approach

of the present invention is based on determining what corrections must be added to the theoretical value of an option in order to compensate for the risk of the option in the trading book, e.g., the option portfolio run by the market maker. The key factors selected to achieve the goals of the models are referred to as *building blocks*.

The model of the present invention takes into account many factors that the Black-Scholes model ignores, e.g., factors that are related to transaction cost of re-hedging. For example, in the model described herein, the re-hedging cost of the Vega of the exotic option may be expressed in terms of the convexity cost of the option. By having a long convexity, i.e., a positive convexity in the trader book, a trader can earn money by selling volatility (e.g., selling ATM options) when the volatility is higher and buying volatility when it is lower, without taking a position. The shift of the trigger represents the probability of an option being near the trigger at a time close to the maturity of the option, at which point the re-hedging cost is the most expensive and, thus, the option is most risky.

Since the trader is typically delta hedged, at a knock-out event, the seller of a knock-out option should remove the delta hedge in a stop-loss trade, e.g., by buying back the underlying asset when the market rises or selling the underlying asset when the market declines. In-the-money knock out options are characterized by a growing delta discontinuity towards expiration of the option. As the time of maturity approaches, the delta re-hedging cost near the trigger may rise drastically, and the price of the option reflects the risk near the trigger. It should be noted that the shift of the trigger correction is always positive and thus needs to be properly gauged to express the risk. The gearing reflects some aspects of the time decay of the exotic option because the price of the option will converge to the price of the corresponding Vanilla option if it is not knocked out. Typically, the shorter the option, the more re-hedging is required to account for time decay.

In accordance with an embodiment of the present invention, two quantities are calculated separately, namely, the adjusted mid-market price and the bid/offer spread. According to this embodiment, separate calculations are used for computing the two quantities. The adjusted mid-market price is defined as the middle (i.e. the average) between the bid price and the offer price. As discussed above, the Black-Scholes model provides one price that may be referred to as theoretical mid-market price or theoretical value (TV). The adjusted mid-market price provided by the present invention may be regarded as an adjustment to the Black-Scholes price. Thus the

adjusted mid-market price of the present invention may also be referred to as the corrected theoretical value (CTV). It should be appreciated that, since the final outputs of the model, typically provided to the user, are the bid and offer prices, as discussed below, the use of mid-market price as a reference point for the model of the invention merely for convenience and may be replaced by other arbitrary reference points, for example, a higher or lower value corresponding to some known function of to the mid-market price. The use of mid-market price as a reference for the computations is preferred simply because existing theoretical models for calculating prices of options, such as the Black Scholes model, are typically intended for calculating theoretical mid-market values.

The bid/offer spread, computed according to the preferred embodiment, reflects the risk that is related to re-hedging transaction costs entailed in the option. The building blocks used for corrections in the calculation of the bid/offer spread may be similar to those used to calculate the mid-market price because both the mid-market price and the bid/offer spread are related to the risk of the option. However, the building blocks are used with different relative weights in the two calculations. For example, in some cases terms may "cancel out" calculating the adjusted mid-market price, but, the same terms may have a cumulative effect in calculating the bid/offer spread as separate independent hedging costs that increase the spread.

By way of an overview of the preferred embodiment, referring to Fig.1, at stage 110 the model calculates a theoretical value (TV) using a combination of known algorithms, e.g., based on the Black-Scholes model, or any model assuming that spot undergoes a Brownian motion pattern. This initial TV may be computed in an analytical method or using numerical calculations, as are known in the art. The Black-Scholes model is used in an exemplary embodiment because it is a common benchmark in the industry for pricing derivatives in cases where the underlying asset is assumed to follow a Brownian motion (a stochastic process). The inputs for the TV may include expiration date, class of the option, e.g., knock out, knock in, binary, European digital, etc., strike (when applicable), barrier(s), spot, forward rate to delivery, volatility for the expiration date, and interest rates of currencies. At stage 112, the model calculates corrections and weights to apply to the TV to generate the adjusted mid-market price, also referred to herein as corrected TV (CTV).

In this exemplary embodiment, the building blocks include convexity, risk reversal, intrinsic value, gearing, shift, and Vega. The corresponding corrections may

then include convexity correction, risk reversal correction, intrinsic value correction, gearing correction, shift correction, and Vega profile correction, as described below. Weights are calculated for each correction where some of the weights may be time dependent. At stage 114, the corrections and corresponding weights are applied to the TV to generate the corrected TV. At stage 116, the model calculates the bid/offer spread by combining the different building blocks of the bid/offer spread, e.g., some base value, the Vanilla bid/offer spread, and the various calculated corrections and weights, some of which weights may be time dependent, and which may be different from the weights used to compute the corrected TV. Finally, at stage 118, the bid and offer prices are computed from the corrected TV and the bid/offer spread provided by the model. The preferred embodiment is demonstrated as applied to in-the-money barrier options, by way of example. It should be appreciated that, with appropriate changes, the invention may be applied to any other type of option or option-like financial derivative known in the art.

Reference is made to Figs. 2A-2D, taken sequentially, which schematically illustrate a method for computing adjusted mid-market price and bid/offer spread, and bid and offer prices of a foreign exchange (FX) option, in accordance with an embodiment of the invention. As shown in Fig. 2A, the inputs for the calculation indicated at block 12 preferably include many significant details of the subject option or the relevant market. Option details include information derived from the relevant market, referred to herein as *market conditions*, as well as details defining the option, referred to herein as *parameters*, which may be specified by the user. Market conditions include market information that describes or relates to the subject option, as well as market information not specific to the subject option. Examples of market conditions include spot, volatility, forward rate, and interest rates. Parameters include, for example, strike, trigger value(s), and expiration date(s). The parameters may also include an identification of the type of option, an identification of the underlying asset, e.g., the currencies being exchanged, and other information defining the option. For example, to compute the price of a window knock-out option, the option details may also include the date on which the trigger is activated and the date on which the trigger is deactivated. Values for market conditions, e.g., the current interest rates, forward rates, and the ATM volatility, may be obtained from information available in the market, as is known in the art. The market information is based on assets that are continuously traded in the market and their prices are

available in different forms. For example, the inputs may be based on information taken from screens of market data provided by companies such as REUTERS, Bloomberg, Telerate, etc., and/or directly from brokers, e.g., over the telephone.

Block 14 indicates the computation of the theoretical value (TV) of the option being priced. The algorithm for computing the TV may be based on Black-Scholes or similar models consisting of analytic formulas or simulation methods as are known in the art. In some cases, for example, when computing double knock-out options, the computation may involve summing over infinite series; however, due to the fast convergence of such infinite series, it is generally sufficient to sum the first ten elements of such series. For example, a double knock-out option, which is similar to knock-out option but has two barriers (one above the current spot level and one below), involves summing over an infinite series, but yields acceptable results when only the first ten elements of the series or less are summed.

Continuing reference to Fig. 2A, block 16 indicates the calculation of the strikes and volatility (denoted "Vol") of 25 delta call and put, respectively, i.e. the strikes for which the delta for the given volatility is 25 percent. The implied volatility of the 25 delta call and put may be derived directly from the 25 delta RR and 25 delta butterfly (strangle). Block 18 indicated the input of these two values that may be obtained from the market conditions. As mentioned in the background section above, the 25 delta RR and 25 delta strangle (butterfly) are commodities in the options market and quotes for those inputs are readily available from well known online sources, as is the case for the ATM volatility.

Block 20 indicates the calculation of derivatives of Vega including the convexity of the 25 delta strangle, the slope of Vega over spot of the 25 delta risk reversal, as well as the price per convexity and price per risk reversal. These quantities may be used to gauge the corresponding derivatives of the exotic option. By comparing the premium (i.e., the price) of the 25 delta strangle to the premium of the 25 delta strangle with ATM volatility, the model may compute the price of a unit of convexity, denoted "Price(convexity)". By comparing the price being paid for 25 delta RR versus ATM, the model may calculate the price of one unit of dVega/dSpot, also denoted "Price(RR)". At this stage of the computation, all the relevant values for 25 delta are computed. Next, the strikes and volatility values for other values of delta, within a preset range, may be computed. Block 22 indicates the calculation of Vega from the TV used in the computation indicated by block 20.

As indicated at block 24, the strikes and volatility for each delta are computed and may be calculated directly or arranged in memory, e.g., in the form of a look-up table, for reference later in the computation. The table generated indicates the relationship between the strike and volatility so that the volatility for a given strike may be looked up in the table. The algorithm for generating this look-up table, also referred to as volatility smile adjustment, is described in detail below, following the description of computing the bid and offer prices. The novel volatility smile adjustment mechanism in accordance with the present invention is not limited to computation of exotic options, as described herein; rather, this novel mechanism has a general applicability and may also be used independently for obtaining the mid-market price of Vanilla options.

Referring now to Fig. 2B, the corrections and weights are calculated for the particular option, as indicated at block 32. The corrections are denoted, respectively, as follows: convexity correction at block 38; risk reversal correction at block 44; intrinsic value correction at block 40; gearing correction at block 34; shift correction at block 42; and Vega profile correction at block 36. It should be noted by one skilled in the art that additional corrections may be used in the computation of the corrected TV and bid/offer spread, and similarly not all of the corrections listed herein need be used to produce valuable results for a particular option. The corrections used in the exemplary embodiment described herein may be defined as follows:

(a) Convexity correction = convexity * Price(Convexity)

(b) Risk reversal correction = (dVega/dSpot)* Price(RR)

(c) Intrinsic value correction = intrinsic value

(d) Gearing correction = (TV(Vanilla)-TV(exotic))*Ratio

wherein Ratio is a function dependent on the ratio between TV(Vanilla) and TV(exotic), for example, as follows:

Ratio= sqrt [(TV(Vanilla)/TV(exotic))/8.5] if V(Vanilla)/TV(exotic)<=8.5

and Ratio=exp(-(TV(Vanilla)/TV(exotic)-8.5)/80) otherwise.

(e) Shift correction is a function of the change in the TV when the barrier is shifted and the change in TV when the expiration is shifted. The following formula may be used:

Shift= abs(TV(exotic with barrier B and expiration t) - TV(exotic with barrier B' and expiration t'))

wherein $|B'-K|/B' = 1.05 * |B-K|/B$ and $t'=t+1day$.

(f) Vega Profile correction is a function of the behavior of the Vega of the exotic option as a function of the spot, e.g., in several spot points. The Vega Profile correction quantifies the shape of the Vega as a function of the spot. The Vega profile corrections may be calculated in 3 steps, providing different aspects of the shape of the Vega profile, namely, Profile1, Profile2, and Profile3.

1. Using K as the strike of the exotic option and B as the trigger (barrier) of the exotic option:

   Profile1=Smile(K) + Smile(B) * (Vega(exotic)-Vega(Vanilla with strike K)) / Vega(Vanilla with strike B)

2. Profile2 is determined by replicating the Vega of the exotic option with, for example, three Vanilla options with strikes K, Kmin, and B, at spot points, S, Smin and B, respectively. The replication is performed by looking for numbers p, q, and r, for which the following equation is satisfied (at the spot points, S, Smin and the barrier, B):

   Vega(exotic at spot X) = p*Vega(Vanilla with strike K, at spot X) + q*Vega(Vanilla with strike Kmin, at spot X) + r*Vega(Vanilla with strike B, at spot X)

   wherein X = S, Smin, and B, sequentially.

   It is noted that (Vega(exotic at spot B) is equal to zero because the option terminates at spot B.

   In the above equations, Vega(Vanilla with strike K, at spot X) refers to the calculation of the Vega of the vanilla option at spot X using the volatility which corresponds to the strike through the Volatility Smile, i.e., find Smile(K), then find the volatility VolK such thatTV(vanilla with strike K, volatility VolK) = TV(Vanilla with strike K and ATM volatility) + Smile(K), then, using VolK, find Vega (Vanilla with strike K and volatility VolK)

   The numbers p, q, and r, are obtained by solving the three equations with three unknowns above. Accordingly:

   Profile2=p*Smile(K) + q* Smile(Kmin) + r*Smile(B)

3. Profile3= Smile(Kmin)*Ratio(Vega (Smin)/Vega (Kmin))

After calculated Profile1, Profile2 and Profile3, the following formula may be applied:

TotalProfile = minimum ((1-Ptouch)*(0.115*Profile1+0.55*Profile2),0) if Profile3<0, and TotalProfile = 0 otherwise.

wherein Ptouch(t) is the probability of touching the trigger prior to time t.

The Vega Profile correction may then be obtained as follows:

Vega Profile correction = Maximum(TotalProfile, Profile3) + (1-exp(3Π/2*t) * Minimum(TotalProfile, Profile3) if Profile3<0, and

Vega Profile Correction = 0 otherwise.

In this embodiment, there is a building block corresponding to each correction indicated by blocks 34-44. The building blocks and other values needed to compute the corrections are based on the values determined at blocks 16-24 of Fig. 2A, using option parameters and market conditions. *Convexity* is defined as dVega/dVol. *Price(Convexity)* is the average Vega of the 25 delta call and put Vanilla options multiplied by the butterfly and divided by the dVega/dVol of the 25 delta strangle. *Risk Reversal* is defined as dVega/dSpot. *Price(RR)* is the average Vega of the 25 delta call and put Vanilla options multiplied by the RR and divided by dVega/dSpot of the 25 delta Risk Reversal. *Intrinsic value* is the distance between a given trigger value and the strike, normalized by the trigger value. *Gearing* is the difference in price between the exotic option with the given trigger and a corresponding Vanilla option with the same strike. *TV(exotic)* is the theoretical value of the original exotic option as calculated by the Black-Scholes model. *TV(Vanilla)* is the theoretical value of the corresponding Vanilla option, i.e. the option with the same parameters except for the triggers. Ratio(TV(exotic)/TV(Vanilla)) is the ratio between TV(exotic) and TV(Vanilla) subject to a cut-off when the ratio exceeds a predetermined value, for example, a value between 6 and 12.

The gearing correction is proportional to the difference and ratio between the theoretical values of the exotic option and a Vanilla option with the same parameters. For each exotic option with a strike, there is a corresponding Vanilla option. For example, a knock-out option has a trigger or barrier. A Vanilla option corresponding to this exotic option will have the same maturity time, spot, strike, etc. but no barrier. Since adding a knock out barrier limits the validity of the option, e.g., it is possible that the exotic option knocks out (i.e., terminates) while the corresponding Vanilla option ends up in the money, the exotic option would generally be less expensive than the corresponding Vanilla option. The gearing correction depends on the ratio and difference between the TV of the Vanilla option and the TV of the exotic option.

The shift correction is a function of two values: the change in TV when the trigger is shifted, and the change in TV when the expiration is shifted. The shift correction function may be, for example, the maximum of these two values. Alternatively the function may be the sum of these two values. The first value may be computed by shifting the trigger so that the intrinsic value is increased by a certain percentage, e.g., 5 percent, and determining the resultant change in the TV. The second value may be computed by shifting the expiration by, for example, one day, and determining the change in TV. The shift correction is a measure of the sensitivity of the theoretical value (TV) of the option price to changes in the trigger value and expiration.

The Vega profile correction requires characterizing the profile of the Vega with respect to the spot. Such characterization may involve, for example, the following factors: *Vega (Smin); Vega (Kmin);* and *Smile(Kmin)*. Vega (Smin) is the Vega of the barrier option at a spot, Smin, which produces the minimum value of Vega. In other words, Smin is the minimum of the Vega of the exotic option with respect to the spot. Vega (Kmin) is the Vega of the Vanilla option with strike, Kmin. Smile(Kmin) is the smile adjustment, i.e., the adjustment of the price of a Vanilla option, with a strike Kmin. Kmin may be computed using the following equation:

$$Smin = Kmin * (\text{current Forward rate})/(\text{current spot rate})$$

Thus, Kmin is the strike that yields a forward rate of Smin at current interest rates.

The volatility of the option may be determined by finding, in the look-up table, denoted by block 30, the volatility for the computed strike, i.e. Kmin. It should be appreciated by persons skilled in the art that characterization of the Vega profile with respect to the spot may also be performed using other suitable parameters, for example, in certain cases, instead of using one strike value (e.g., Kmin), as described above, more than one strike value may be used to approximate the Vega profile.

Once the above-described corrections are computed, they are added to the TV, either directly or with some restrictions, using time dependent weights as described in detail below, producing the total corrected TV. The weights of the corrections generally reflect the risk involved in each correction. For example, some of the corrections, e.g., the gearing correction, have an enhanced influence close to the maturity of the option, but very small influence when the option is far from maturity. Other corrections, e.g., the convexity correction, have less of an influence close to the

maturity. Therefore the weights are generally tailored to adjust for the specific risk versus time-to-maturity behavior of each of the corrections.

The motivation for adding weighted corrections to the TV, in accordance with the invention, is partly based on the realization by the inventors that models such as the Black-Scholes model underestimate the probability of reaching a far spot level when time to maturity is long. In reality, the probability for a far knock out is generally higher than that anticipated by the Black-Scholes formula. This is part of the reason for the decay of most of the factors with time to maturity beyond a certain level. This type of adjustment may be particularly valuable when calculating prices of "one touch" options, i.e., options where the buyer receives a certain payout if the spot touches the barrier,

For the class of in-the-money knock out options, (also called Reverse Knock out options) the weights used for the computation of the corrected TV, wherein Ca denotes the time-dependent weight for correction (a), Cb denotes the time-dependent weight for correction (b), etc., are as follows:

$Ca = 0.61* \exp(-0.4*t)* (1-Ptouch(t/L) * W*LT$

wherein $L= 2$ if $t>1$, $L=1$ if $t<1/12$, and $L=1+(t-1/12)*12/11$ otherwise;

$W= (0.5+0.5*(25Delta\ butterfly-0.5))/ 25Delta\ butterfly$ if $25Delta\ butterfly >=0.5$, $W=1$ otherwise; and

$LT = 2*sqrt(t)$ if $t<0.25$, and $LT=1$ otherwise.

$Cb = 0.6* \Pi* sqrt(t) * \exp(-t*\Pi/2))*(1-Ptouch(t/L))$

wherein L is as defined above.

$Cc = 0$

$Cd = 0.045* minimum(1, 4.5* \exp(-12t) +\exp(-1))$

$Ce = 0.135*t+0.1125$ if $t<1$, and 0.2475 otherwise

$Cf = (0.5+\exp(-2* \Pi*t))*(1- \exp(-2* \Pi*t))$

wherein Ptouch(t) is the probability of touching the trigger prior to time t, denoted in years (E.g. for one year t=1.)

As indicated at blocks 46 and 50, following the computation of the corrections and weights for a given option, the corrected TV (CTV), i.e., the adjusted mid-market price, may be computed using all the blocks. In combining the building blocks of the invention, several issues should be addressed. First, the Risk Reversal correction and the Convexity correction are local in the sense that they relate to the near vicinity of the spot range, whereas the Vega Profile correction is a global correction, i.e., the

correction takes into account the Vega of the exotic option in a relatively wide spot area. In a certain area of the spot range, part of the quantified value of the profile is already taken into account in the Risk Reversal correction and the convexity correction and vice versa and, therefore, duplications should be avoided. For example, if the value of the profile is determined to resemble a certain Vanilla option, then the Vega Profile correction may take into account the Smile adjustment of that Vanilla and, therefore, adding the Risk Reversal correction and Convexity correction could result in double counting, in view of the smile adjustment mechanism used. Second, the Risk Reversal correction and the Convexity correction are linear in the 25 Delta RR and butterfly. In addition to removing the linearity in these factors, the Vega Profile correction should include higher order derivatives and should remove the linearity, as long as it is combined properly with the Risk Reversal Correction and Convexity correction. Third, in some cases, the Gearing correction and the Shift correction may overlap the quantified risk involved in ending up near the trigger. This may happen particularly in the vicinity of the spot, where both these corrections tend to maximize.

Taking the above considerations into account, the following mechanism may be used to combine the building blocks, wherein building block are added one by one. For this process, the following corrections are defined:

a- Convexity correction
b- Risk Reversal correction
c- Intrinsic value correction
d- Gearing correction
e- Shift correction
f- Vega Profile correction

1. Combining the Risk Reversal correction with the Vega profile correction:

If Risk Reversal correction>=0 and Vega profile correction<=0 then

Correction1 = Cb*b + Cf*f

Otherwise

Correction1=exp(-3/2* Π*t) * LLT * maximum(Cb*b, Cf*f) + minimum(Cb*b, Cf*f)

wherein LLT= 4*t if t<0.25, and LLT=1 otherwise.

2. Combining Correction1 with the Convexity correction:

If Convexity correction<0 and Correction1<0, then:

set LowCutOff(t) = 8% if t<=1/12, LowCutOff = 15% if t>1, and

LowCutOff = 8% +7%*(t-1/12)*12/11 otherwise.

Set HighCutOff(t) = 18% if t<=1/12, HighCutOff = 20% if t>1, and

HighCutOff = 18% +2%*(t-1/12)*12/11 otherwise.

Set ConvexityRatio = Ca*a /TV(exotic).

If ConvexityRatio> LowCutOff(t) , then

set ProfileFactor = maximum(0.5 , 1-0.5*(ConvexityRatio - LowCutOff(t))/(HighCutOff(t) - LowCutOff(t))).

If Convexity correction<0 and Correction1>0, then ProfileFactor =1.

If Convexity correction>0 and Correction1<0, then ProfileFactor =1.

Finally, Correction2= ProfileFactor * Correction1 + a*Ca

4. Combining Correction2 with the Shift correction and the Gearing correction:

Set Fshift=0 if Ce*e=<0.07%, Fshift=1 if Ce*e>=0.09%, and

Fshift=(Ce*e-0.07%)/0.02% otherwise.

Set Fgearing=0 if Cd*d=<0.07%, Fgearing=1 if Cd*d >=0.09%, and

Fgearing=(Cd*d-0.07%)/0.02% otherwise.

Fcombine(t) = 0 if t=<0.019, Fcombine(t) = (t-0.019)/(0.0641) if 0.019=<t<=1/12, Fcombine(t) = 1 if 1/12=< t=<0.41 , Fcombine(t) = 1-(t-0.41)/(0.59) if 0.41=< t<=1, and Fcombine(t) = 0 otherwise.

Correction3 = Correction2+ Ce*e + Cd*d – Ptouch * (Ce*e + Cd*d - (0.16%+0.05% * minimum (t,1))* Fshift * Fgearing * Fcombine(t)

Finally, Total Correction=Correction3, and:

CTV = TV+ Total Correction

wherein TV is the theoretical value.

Referring now to Fig. 2C, the bid/offer spread may be computed based on the same set of corrections along with a different set of weights, some of which may be time dependent. These new weights may be functions of the underlying corrections. Using the newly calculated weights, the corrections are summed, yielding the bid-offer spread. Block 52 indicates computing the new weights, blocks 54-64 indicate the corrections for computing the sum, block 66 indicates summing of the weighted corrections, and block 68 indicated computing the bid/offer spread.

The bid/offer spread of the exotic option may depend also on the bid/offer spread of the corresponding Vanilla option in the current market conditions. The spread of an exotic option per Vega is generally wider than that of the corresponding Vanilla, for example, by a factor of about 1.5 * (Vega of the exotic)/(Vega of the ATM Vanilla), or higher. Therefore, the bid/offer spread of the ATM Vanilla option may be used as a base value in the bid/offer spread computation of the preferred embodiment. It should be appreciated, however, that other suitable factors may be used in addition to or instead of the Vanilla bid/offer spread in formulating the base value for the bid/offer spread calculation in accordance with the invention. The remaining factors may be the same as those used for computing the corrected TV, as described below, or different building blocks may be used for the bid/offer spread computation, based on the principles discussed above, to adapt for particular option types. The corrections, as applied to the computation of the bid/offer spread, are indicated in Fig. 2C as follows: convexity correction at block 58; risk reversal correction at block 64; intrinsic value correction at block 60; gearing correction at block 54; shift correction at block 62; and Vega Profile correction (also referred to as "Vega correction" for short) at block 56.

Since the bid/offer spread is related to the risk/transaction cost of re-hedging, the corrections have similar properties as those used for the adjusted mid-market price. However the different corrections are added in the bid/offer spread calculation with absolute values because the transaction costs involved in re-hedging the different parameters are generally independent. For example, an option may have a positive convexity, which lowers the price, and a negative risk reversal, which raises the price, causing an over-all small change in the CTV. However, hedging the convexity is independent of hedging the risk reversal and, therefore, these two corrections result in a wider bid/offer spread. In this regard, the "double counting" considerations discussed above should be taken into account in calculating the Total Correction. The weights applied to the corrections are denoted Sa, Sb, Sc, Sd, Se, and Sf, respectively. These weights are calculated as follows:

$Sa = 1/1.55$

$Sb = 0.2$

$Sc = \text{minimum}(1,(1-TV(\text{exotic})/TV(\text{Vanilla}))/0.15)$

$Sd = 0.018 * \exp(-t)$

$Se = 0.45*\exp(-1.6t)$

Sf = 0.2

In an embodiment of the invention, in order to calculate the Bid/Offer spread, the building blocks may be combined in three steps, as follows.

1. The convexity correction is added to the combined correction of the Risk Reversal correction and Vega Profile correction, which combined correction is computed as discussed above with reference to Total Correction.

Thus, Spread1= Sf * abs(Correction1) + Sa * abs(a) + minimum (Sc*c, 0.1%)

Wherein "abs" denotes absolute value. It should be noted that if the Risk Reversal correction and the Vega Profile correction have opposite signs, then Sf * abs(Correction1) becomes abs(Sf*Cf*f + Sb*Cb*b).

2. To combine the shift correction and the gearing correction, the following parameters are defined:

ShiftTrim = e if e =< 0.15% and ShiftTrim = 0.15%+0.5*(e - 0.15%) otherwise.

GearingTrim = Sd*d if Sd*d =< 0.08%, and GearingTrim= 0.08% +0.5 * (Sd*d – 0.08%) otherwise.

Spread2 = Spread1 + Se* ((1-Fcombine(t))*e + Fcombine(t) * ShiftTrim) + Sd*((1-Fcombine(t))*d + Fcombine(t) * GearingTrim/Sd)

3. Add standard Vanilla Bid/offer spread.

Finally we obtain:

Bid/offer spread = (0.7+0.42* exp(-1.1t)) * Spread2 + VanillaSpread (K) + maximum (VegaATM * ATM Volatility Bid/Offer spread- VanillaSpread(K), 0) * minimum (1, Vega of the exotic option/VegaATM)

wherein VanillaSpread (K) is the bid/offer spread of the Vanilla option with the same strike as the exotic option and VegaATM is the Vega of the ATM Vanilla option.

Reference is now made to Fig. 2D. After computing the bid/offer spread, the bid and the offer prices are computed, as indicated at block 70, by subtracting and adding, respectively, one half (0.5) of the bid/offer spread to the average price calculated. Hence, as denoted at block 72, the bid is the adjusted mid-market price (CTV) minus half the spread, and the offer is the adjusted mid-market price (CTV) plus half the spread, as indicated at block 74.

As discussed above with reference to calculating the smile adjustment for Vanilla options and the generation of the look-up table at block 24 (Fig. 2A), the algorithm for computation of the volatility smile adjustment for Vanilla options has general applicability, as is demonstrated below in the context of calculating the

bid/offer spread for the Vanilla option. Therefore, the present invention also includes a method for pricing Vanilla options for any given strike. The volatility smile adjustment is calculated from the volatility of an At-The-Money (ATM) Vanilla option and 25Delta call and put options. The factors used in calculating the volatility smile include Vega, dVega/dSpot (i.e., risk reversal), and dVega/dVol (i.e., convexity). Vega is the partial derivative of the option value (price) with respect to the volatility. dVega/dSpot is the partial derivative of the Vega with respect to the spot, and dVega/dVol is the partial derivative of the Vega with respect to the volatility.

Two additional factors, derived from market conditions, used in calculating the volatility smile adjustment include 25delta butterfly and 25delta Risk Reversal, both measured in units of volatility. It should be noted that for the purpose of the algorithm for the Volatility Smile, in accordance with the invention, it is not important that the inputs be 25delta butterfly and 25delta Risk Reversal. The input may also be of any two other strikes for which market volatility may be obtained, or even two pairs of strikes, for which the total premium in the market is known. Since the model of the invention applies an iteration method, the 25delta butterfly and 25delta Risk Reversal can be deduced from the data. For example, in some markets, e.g. currency options, the 25delta butterfly is traded in the market with strikes that correspond to the same volatility for both the call and the put options. In such case, the model can obtain the "true" 25delta butterfly by iteration, so that the total premium of the two strikes coincides with their smile. As another example, the ATM volatility and the 25 delta RR and butterfly for equity derivatives may be inferred from the price of three options that are traded in the exchange for the same expiration date. This versatility exemplifies the general applicability of the model of the present invention.

As discussed above, the 25delta butterfly and 25delta Risk Reversal factors are defined or calculated as follows:

25delta butterfly = 0.5*(implied Vol(25delta call) + implied Vol(25delta put)) – ATM Vol.

25delta risk reversal = implied Vol(25delta call) - implied Vol(25delta put)

The volatilities of the 25delta options may be calculated from these two factors. Using multiple iterations, the entire volatility smile may be calculated, e.g., a look-up-table may be constructed linking strikes to corresponding deltas and volatility

values. Hence, starting with the volatility of an at-the-money option, which is known, volatilities for the option at various different deltas (i.e., not only ATM) may be computed using the 25 delta butterfly and 25 delta risk reversal. Each set of strike-volatility-delta is unique and may be included in the look-up-table for easy reference later in the algorithm.

Thus, the smile adjustment for Vanilla options may be computed starting with the following inputs: 25 delta risk reversal; 25 delta strangles (butterfly); ATM volatility; spot; forward rate; and interest rates. The algorithm for calculating the smile adjustment may include the following steps:

1. For a given delta, D1, find the strikes of the D1 delta strangle. If D1 is less than a predetermined value, e.g., 30, use the 25 delta implied volatility, obtained from the RR and the strangles; otherwise use the ATM implied volatility.
2. Calculate the following: dVega/dVol of the D1 strangle* Price(convexity) and dVega/dSpot of D1 (RR)* Price(RR); wherein Price(convexity) and Price(RR) are calculated from the 25 delta strangle and 25 delta RR, as discussed above.
3. Calculate a desired premium for D1 strangle over its premium with ATM volatility, by requiring the same price for one unit of convexity as the price for one unit of 25 delta strangle. Repeat this calculation for the dVega/dSpot.
4. Adjust the implied volatility of the D1 strikes to fulfill the same price for a unit of convexity as for the 25 delta butterfly, and the same for a unit of dVega/dSpot as for the 25 delta risk reversal.
5. Calculate new strikes corresponding to delta D1 with the volatility in step 4.
6. Repeat steps 3-5 sequentially until convergence is achieved.
7. Set the last volatility obtained as the implied volatility for D1 strikes.
8. Repeat steps 1-7 for other deltas to create a look-up-table of strikes and their implied volatility.
9. For strikes positioned between those in the look-up-table, use interpolation based on the values of the look-up-table. It should be noted that the smile adjustment for a given strike is independent of whether the option is a call option or a put option.

In an alternative embodiment, the method of the present invention can be used to calculate SmileAdjustment for stike K directly, i.e., not based on a look-up-table, as follows:

1. For a given strike K, calculate delta D1. Find the strike K_1 so that K and K_1 are the strikes of the D1 delta strangle. If D1 is below a predetermined value, e.g., 30, use the 25 delta implied volatility obtained from the RR and the strangles, i.e. the 25 delta call volatility for maximum(K,K_1) and the 25 delta put volatility for minimum(K,K_1). Otherwise, use the ATM implied volatility for both strikes.

2. Calculate the following: dVega/dVol of the D1 strangle* Price(convexity) and dVega/dSpot of D1 (RR)* Price(RR), wherein Price(convexity) and Price(RR) are calculated from the 25 delta strangle and 25 delta RR, as discussed above.

3. Calculate a desired premium for D1 strangle over its premium with ATM volatility, by requiring the same price for one unit of convexity as the price for one unit of 25 delta strangle. Repeat this calculation for the dVega/dSpot.

4. Adjust the implied volatility of the D1 strikes to fulfill the same price for a unit of convexity as for the 25delta butterfly, and the same for a unit of dVega/dSpot as for the 25 delta risk reversal.

5. Calculate new Delta D2 of strike K with the volatility obtained for stike K in step 4. Calculate the strike K_2, so that K and K_2 are the strikes of the D2 delta strangle with the volatility for K_1 in step 4.

6. Repeat steps 3-5 sequentially until the volatility of strike K converges.

7. Set the last volatility obtained as the implied volatility for strike K.

The computation presented above for the bid/offer spread has general applicability as is demonstrated by the following algorithm for computing the bid/offer spread for Vanilla options. The input for this computation may include the bid/offer spread of the ATM volatility, as is known in the art. The market data input may include both bid and offer ATM volatilities. The algorithm for computing the bid/offer spread may be as follows:

1. Calculate the bid/offer spread of the ATM option in basis points ("bp"), i.e., in units corresponding to 1/100 of a percent of the quantity being traded. This may also be approximated using the following formula:

SpreadATM = Vega(ATM)*(bid/offer spread of volatility).

2. Calculate the smile adjusted volatility for a given strike, K. Calculate the delta that corresponds to strike K, denoted delta (K), by taking the call if the strike is above the ATM Strike (roughly equal to the forward rate) and take the put if the strike is below the ATM Strike. As a reminder, the ATM strike is the strike for which the sum of the delta of the call option and the delta of the put option is zero.

3. Calculate the bid offer spread for strike K in basis points (bp), as follows:

Spread(K) = VegaATM * ATM Volatility Bid/Offer spread * G(Delta, TV)

wherein G(Delta, TV)=1 if Delta(K)>=7%,

G(Delta, TV)= 1-0.645*exp(-15* (VanillaTV(K) + maximum(Smile(K),0)))

if Delta(K)=<7% and (VanillaTV(K) + maximum(Smile(K),0)) >=0.001%, and

G(Delta, TV)= 0.5*(1-exp(-1300* (VanillaTV(K) + maximum(Smile(K),0)))

if Delta(K)=<7% and (VanillaTV(K) + maximum(Smile(K),0)) =<0.001%.

In the above exponentials the TV is measured in percentage units.

4. Calculate the bid price and offer price as follows:

Bid-Price(K) = max(Price(K)-0.5*Spread(K), min(Price(K),1bp))

Offer-Price(K)=Bid-Price(K)+Spread(K)

wherein Price(K) denotes the middle price in basis points (bp) of the option being priced.

5. Find Volatility-Bid and Volatility-Offer that correspond to Bid-Price(K) and Offer-Price(K). These volatilities are the bid and offer volatilities.

Reference is now made to Fig. 3, which schematically illustrates a system for pricing financial derivatives in accordance with an embodiment of the invention. As described in detail above, the system includes a database 218 for storing information received from a user 200, including details of an option to be priced, as well as real time data 214, such as market conditions from sources as are known in the art. Market conditions may include, for example, a current spot price for the underlying asset (or other value) subject of the option. The information received from the user and the real time market conditions are processed by an application server 212, which may include any combination of hardware and/or software known in the art for processing and handling information received from various sources. Application

server 212 is preferably associated with a controller, as is known in the art, which controls and synchronizes the operation of different parts of the system. Application server 212 is associated with Bid/Offer processor 216 which executes the method described above with reference to Figs. 2A-2D. The Bid/Offer processor may include any combination of hardware and/or software known in the art capable of executing the algorithms described above with reference to Figs. 2A-2D.

The information from user 200 is preferably received by a web server 210, as is known in the art, which is adapted to communicate with a global communication network 202, e.g., the Internet, via a communication modem, as is known in the art. The user may communicate with web server 210 via the Internet 202 using a personal computer, or any other suitable user interface having a communication modem for establishing connection with the Internet 202, as is known in the art. In other embodiments of the invention, user 200 may communicate with web server 202 directly, for example, using a direct telephone connection or a secure socket layer (SSL) connection, as is known in the art. In an alternative embodiment of the invention, user 200 is connected directly to application server 212, for example, via a local area network (LAN), or via any other local communication network known in the art.

The real time data 214 may be received directly by application server 212 using any direct connection means as are known in the art. Alternatively, the real time data may be received from sources available on the global computer communication network, using web server 210. After computing a bid price and an offer price for the option requested by the user, application server 212 may communicate the computed bid/offer prices to user 200 via web-server 210, as is known in the art, in a format convenient for presentation to the user.

Table 1 below shows three examples demonstrating application of a preferred embodiment of the invention, as described above with reference to Figs.2A-2D. These examples are based on information taken from foreign exchange exotic option brokers on three different dates. The dates appear on the trade date row of the table. The brokers provide the maturity date of the option from which the number of days to maturity is measured. The remaining inputs include the details of the option, for example, option parameters such as strike , put or call, barrier, as well as market conditions relevant to the trade, e.g., spot, forward, ATM volatility, 25 delta RR, 25 delta butterfly, current interest rates, the TV of the exotic option, and the TV of the

corresponding Vanilla option. Actual bid and offer prices for Table 1 are taken from a number of market makers (brokers). The "fair price" entries in Table 1 represent the average of the bid/offer prices presented by the different market makers. The fair market price represents the market price of the option. Finally, the bid and offer prices calculated in accordance with a preferred embodiment of the invention are presented at the bottom of the table, denoted "model price". These prices are generated from the adjusted mid-market prices and the bid/offer spreads as described above. It is evident from Table 1 that the model of the present invention provides a correct bid/offer spread and a correct adjusted mid-market price for the exemplary options computed. It is also evident from Table 1 that the TV calculated based on the Black-Scholes model does not yield correct results.

Referring to Example 1 in Table 1, the option traded on February 12, 1999, has an expiration date of June 14, 1999, i.e., 122 days after trading. Table 1 also presents additional details of the option as discussed above. For example, the spot price for the underlying asset of the option of Example 1 is 114.40, the volatility for this option is 17.35, the forward for this option is –1.86, the theoretical value (TV) calculated based on the Black-Scholes model is 0.38, and the corresponding Vanilla option price and bid/offer spread are 2.7 and 0.25, respectively. Table 1 also presents bid and offer prices for the option of Example 1, provided by 6 different market makers, which may be averaged to yield "fair" bid and offer prices of 0.38 and 0.64, respectively. As further shown in Table 1, the bid and offer "model" prices for the option of Example 1 are 0.38 and 0.64, respectively, which values are identical to the "fair" bid and offer prices, respectively. From analyzing Table 1, one skilled in the art will conclude that the results obtained from the model of the present invention for the option of Example 1 are remarkably close (essentially identical) to the average fair prices of the same option. Similarly, from analyzing the data of Examples 2 and 3 in Table 1, one skilled in the art will appreciate that the "model prices" computed in accordance with the invention for the options of Examples 2 and 3 are substantially identical to the average "fair prices" of these options.

Table 1

	Example 1		Example 2		Example 3	
Interest Rate 1	6.19%		3.10%		6.09%	
Interest Rate 2	0.19%		6.18%		0.17%	
Currency 1	U.S dollar		Eur		U.S. dollar	
Currency 2	Japan yen		U.S. dollar		Japan yen	
Trade Date	12-Feb-99		18-Jan-00		15-Jun-99	
Expiration Date	14-Jun-99		16-Nov-00		15-Dec-99	
Months to Expiration	4		10		6	
Days to Expiration	**122**		**303**		**183**	
Spot	**114.40**		**1.01**		**120.35**	
Volatility	17.35		10.75		12.5	
Forward	-1.86		0.006		-3.15	
Strike	**116.00**		**1.00**		**115.00**	
Put/Call	Call		Call		Put	
Barrier (trigger)	**126.00**		**1.10**		**100.00**	
25 Delta Risk Reversal	-0.375		-0.4		0.1	
25 Delta Butterfly	0.75		0.25		0.55	
Class	RKO		RKO		RKO	
TV (exotic)	**0.38**		**0.655**		**1.64**	
TV (Vanilla)	2.7		5.47		2.565	
Vanilla Bid/Offer spread (Vol)	0.25		0.25		0.25	
Number of prices	6		5		5	
6 market makers	Bid	Offer	Bid	Offer	Bid	Offe
1	0.38	0.70	73	99	129	154
2	0.38	0.65	75	91	124	151.
3	0.36	0.66	75	95	122	152
4	0.38	0.58	73	98	120	150
5	0.40	0.60	76	89	125	150

6	0.39	0.64				
Fair Price (Bid/Offer)	0.38	0.64	.75	.94	1.24	1.51
Model Price (Bid/Offer)	0.38	0.64	.75	.94	1.24	1.51

It should be appreciated that the benefit to financial markets from having an accurate model to price derivatives are enormous. First, the accurate model of the invention enables less experienced users of derivatives to price them accurately. This advantage alone is important because dealing at wrong prices causes substantial financial losses. Second, by virtue of having an accurate pricing model, the derivatives market is expected to become more liquid. Not being able to determine the correct price of derivatives creates strong dependency on market makers and causes users to refrain from using derivatives. By increasing the use of derivatives, corporations and other hedgers can better hedge their cash flows. Third, currently, many corporations and funds, for example, cannot establish credit lines vis-à-vis each other and are required to deal only with banks. Setting up credit lines is a complicated task and requires a lot of information about the company requesting the credit line. Many small companies, for example, cannot establish credit lines and are thus prevented from using derivatives for their hedges. By having an accurate model for market prices any two parties can deal with each other on a margin basis, even if they do not have mutual credit lines. For example, such parties can set a margin on the price of the derivative, as is used in exchanges, that includes the current loss for the seller relative to the current market price. Thus if one of the counter parties defaults during the life of the option, the other one can unwind the derivative with another party at no loss.

The following example illustrates an exemplary margin system. Assuming that the value calculated by the model of the present invention for the market price of a given derivative at a given time, t, is P(t). The price P(t) may be the middle between the bid price and the offer price, or the offer price, or any other agreed upon function of the bid price and/or the offer price. The premium paid at the execution of the deal is P(0). The margin amount, in money terms, is denoted M. In this example, at time, t, the seller of the derivative must have in his margin account for the buyer of the

derivative the following amount:

$$M(t)=\max(0, P(t)-P(0)) +X$$

wherein X can be any positive amount on which the two sides agree upon in advance and is designed to protect the buyer against abrupt moves in the market. X can also be proportional to the bid/offer price of the option, at time t. If at some point in time the margin account reaches zero, then the buyer of the derivative may have the right to close his/her position with the seller and buy the option from a third party.

As a result, in the above example, the market will be open to many more users, e.g., corporations, funds, private investors, and other derivatives users, who can save considerable amounts of money compared to their situation today. For example, such users would be able to deal at better prices with a variety of corporations and would not be limited to deal only with the community of market maker. e.g., banks or specialized brokers, with whom they have succeeded to establish credit lines. It should be appreciated that such development would increase the liquidity of derivatives dramatically.

While the embodiments of the invention shown and described herein are fully capable of achieving the results desired, it is to be understood that these embodiments have been shown and described for purposes of illustration only and not for purposes of limitation. Other variations in the form and details that occur to those skilled in the art and that are within the spirit and scope of the invention are not specifically addressed. Therefore, the invention is limited only by the appended claims.

CLAIMS

1. A computer based data processing method comprising the steps of:

receiving first input data corresponding to a plurality of parameters defining an option on an underlying asset;

receiving second input data corresponding to a plurality of current market conditions relating to said underlying asset;

computing a corrected theoretical value (TV) of said option based on at least part of said first and second input data;

computing a bid/offer spread of said option based on at least part of said first and second input data;

computing a bid price and/or an offer price of said option based on said corrected TV and said bid/offer spread;

providing an output corresponding to the bid price and/or the offer price of said option.

2. A method according to claim 1 wherein said first input data comprises an indication of at least one parameter selected from the group including a type of said option, an expiration date of said option, and a trigger for said option.

3. A method according to claim 1 or claim 2 wherein said second input data comprises an indication of at least one market condition selected from the group including a spot value, an interest rate, a volatility, an at-the-money volatility, a 25 delta risk reversal, a 25 delta butterfly, and a 25 delta strangle.

4. A method according to any of claims 1-3 wherein the step of computing said corrected theoretical value comprises the steps of:

computing a theoretical value (TV) of said option based on at least part of said first and second input data; and

correcting said TV based on at least part of said first and second data to yield said corrected TV.

5. A method according to claim 4 wherein the step of correcting said TV

comprises the steps of:

computing a plurality of TV corrections based on at least part of said first and second input data; and

applying said plurality of TV corrections to said TV.

6. A method according to claim 5 wherein at least one of said plurality of TV corrections is a function of at least one factor related to a risk associated with said option.

7. A method according to claim 6 wherein said plurality of TV corrections comprise at least one correction selected from the group including a convexity correction, a risk reversal correction, a shift correction, a gearing correction, a Vega Profile correction, and an intrinsic value correction.

8. A method according to any of claims 5-7 wherein the step of applying said TV corrections to said TV comprises the steps of:

computing a TV correction weight associated with each of said TV corrections based on at least part of said first and second data;

multiplying each of said TV corrections by the associated TV correction weight yielding corresponding weighted TV corrections; and

adding said weighted TV corrections to said TV.

9. A method according to claim 8 wherein at least one of said TV correction weights is time dependent.

10. A method according to any of claims 1-9 wherein the step of computing said bid/offer spread comprises the steps of:

computing a base value for the bid/offer spread using at least part of said first and second input data; and

correcting said base value using at least part of said first and second data to yield said bid/offer spread.

11. A method according to claim 10 wherein the step of correcting said base value comprises the steps of:

computing a plurality of bid/offer spread corrections based on at least part of said first and second input data; and

applying said plurality of bid/offer spread corrections to said base value.

12. A method according to claim 11 wherein at least one of said plurality of bid/offer spread corrections is a function of at least one factor related to a risk involved in said option.

13. A method according to claim 12 wherein said plurality of bid/offer spread corrections comprise at least one correction selected from the group including convexity correction, risk reversal correction, shift correction, gearing correction, Vega profile correction, and intrinsic value correction.

14. A method according to any of claim 11 - 13 wherein the step of applying said bid/offer spread corrections to said base value comprises the steps of:

computing a bid/offer spread correction weight corresponding to each of said bid/offer spread corrections;

multiplying each of said bid/offer spread corrections by the corresponding bid/offer spread correction weight yielding weighted bid/offer spread corrections; and

adding said weighted bid/offer spread corrections to said base value.

15. A method according to claim 14 wherein at least one of said bid/offer spread correction weights is time dependent.

16. A method according to any of claims 1-15 wherein said underlying asset comprises a financial asset.

17. A method according to claim 16 wherein said option is a foreign exchange (FX) option.

18. A method according to claim 17 wherein said FX option is a Vanilla option.

19. A method according to any of claims 1-16 wherein said option comprises an option-like financial derivative.

20. A method according to any of claims 1-17 or 19 wherein said option is an exotic option.

21. An apparatus for providing a bid price and/or an offer price of an option on an underlying asset comprising a server receiving first input data corresponding to a plurality of parameters defining said option and providing an output corresponding to a bid price and/or an offer price of said option, the server further receiving second input data corresponding to a plurality of current market conditions relating to said underlying asset; and a processor, associated with said server, which computes, based on at least part of

said first and second input data, a corrected theoretical value (CTV) of said option and a bid/offer spread of said option, and which further computes, based on said CTV and bid/offer spread, the bid price and/or the offer price of said option.

22. An apparatus according to claim 21 wherein said first data comprises an indication of at least one parameters selected from the group consisting of a type of said option, an expiration date of said option, and a trigger for said option.

23. An apparatus according to claim 21 or claim 22 wherein said second data comprises an indication of at least one market condition selected from the group consisting of a spot value, an interest rate, a volatility, an at the money volatility, a 25 delta risk reversal, a 25 delta butterfly, and a 25 delta strangle.

24. An apparatus according to any of claims 21-23 wherein, in computing said CTV, said processor computes a theoretical value (TV) of said option and corrects said TV, based on at least part of said first and second data, to yield said CTV.

25. An apparatus according to claim 23 or claim 24 wherein, in correcting said TV, said processor computes a plurality of TV corrections based on at least part of said first and second input data and applies said plurality of TV corrections to said TV.

26. An apparatus according to claim 25 wherein at least one of said corrections is a function of at least one factor related to a risk associated with said option.

27. An apparatus according to claim 26 wherein said plurality of TV corrections comprise at least one correction selected from the group consisting of convexity correction, a risk reversal correction, a shift correction, a gearing correction, a Vega profile correction, and an intrinsic value correction.

28. An apparatus according to any of claims 25-27 wherein, in applying said TV corrections to said TV, said processor computes a TV correction weight for each of said TV corrections, multiplies each of said TV corrections by its TV correction weight to yield a corresponding weighted TV correction, and adds said weighted TV

corrections to said TV.

29. An apparatus according to claim 28 wherein at least one of said TV correction weights is time dependent.

30. An apparatus according to any of claims 21-29 wherein, in computing said bid/offer spread, said processor computes a base value for the bid/offer spread and corrects said base value, based on at least part of said first and second data, to yield said bid/offer spread.

31. An apparatus according to claim 30 wherein, in correcting said base value, said processor computes a plurality of bid/offer spread corrections and applies said plurality of bid/offer spread corrections to said base value.

32. An apparatus according to claim 31 wherein at least one of said bid/offer spread corrections is a function of at least one factor related to a risk associated with said option.

33. An apparatus according to claim 32 wherein said plurality of bid/offer spread corrections comprise at least one correction selected from the group consisting of a convexity correction, a risk reversal correction, a shift correction, a gearing correction, a Vega profile correction, and an intrinsic value correction.

34. An apparatus according to any of claims 31-33 wherein, in applying said bid/offer spread corrections to said base value, said processor computes a bid/offer spread correction weight for each of said bid/offer spread corrections, multiplies each of said bid/offer spread corrections by its bid/offer spread correction weight to yield a corresponding weighted bid/offer spread correction, and adds said weighted bid/offer spread corrections to said base value.

35. An apparatus according to claim 34 wherein at least one of said bid/offer spread correction weights is time dependent.

36. An apparatus according to any of claims 21-35 wherein said underlying asset comprises a financial asset.

37. An apparatus according to claim 36 wherein said option is a foreign exchange (FX) option.

38. An apparatus according to claim 37 wherein said option FX option is a Vanilla option.

39. An apparatus according to any of claims 21-36 wherein said option comprises an option-like financial derivative.

40. An apparatus according to any of claims 21-37 or 39 wherein said option is an exotic option.

41. A computer based data processing method comprising the steps of:

receiving first input data corresponding to a plurality of parameters defining an option on an underlying asset;

receiving second input data corresponding to a plurality of current market conditions relating to said underlying asset;

computing a plurality of building blocks based on at least part of said first and second input data, at least one of said building blocks being a function of a factor related to a risk associated with said option;

computing a bid price and/or an offer price of said option as a function of at least some of said building blocks; and

providing an output corresponding to the bid price and/or the offer price of said option.

42. A method according to claim 41 wherein the step of computing said bid price and/or said offer price comprises the steps of:

computing a corrected theoretical value of said option as a first function of at least some of said building blocks;

computing a bid/offer spread of said option as a second function of at least some of said building blocks; and

computing said bid price and/or said offer price of said option based on said corrected TV and said bid/offer spread.

43. A method according to claim 41 further comprising the steps of:

computing a plurality of corrections based on at least one or said plurality of building blocks;

computing a plurality of weights corresponding to each of said plurality of corrections;

combining said plurality of corrections and said plurality of weights yielding a plurality of weighted corrections; and

computing said bid price and/or offer price as a function of said plurality of weighted corrections.

44. A method according to claim 43 wherein at least one of said plurality of weights is time dependent.

45. A method according to any of claims 41 - 44 wherein said plurality of building blocks comprises at least one building block selected from the group consisting of convexity, risk reversal, shift, gearing, Vega profile, and intrinsic value.

46. A method according to any of claims 41-45 wherein said underlying asset comprises a financial asset.

47. An apparatus for providing a bid price and/or an offer price of an option on an underlying asset, the apparatus comprising: a server receiving first input data corresponding to a plurality of parameters defining said option and providing an output corresponding to a bid price

and/or an offer price of said option, the server further receiving second input data corresponding to a plurality of current market conditions relating to said underlying asset; and

a processor, associated with said server, which computes a plurality of building blocks based on said first and second input data, at least one of said building blocks being a function of at least one factor related to a risk associated with said option, and which further computes the bid price and/or the offer price of said option as a function of at least some of said building blocks.

48. An apparatus according to claim 47 wherein, in computing the bid price and/or offer price of said option, said processor computes a corrected theoretical value of said option as a first function of at least some of said building blocks, a bid/offer spread of said option as a second function of at least some of said building blocks, and wherein the processor computes the bid price and/or offer price of said option based on said corrected TV and said bid/offer spread.

49. An apparatus according to claim 47 wherein said processor further computes a plurality of corrections based on at least one or said plurality of building blocks; a plurality of weights corresponding to each of said plurality of corrections; a plurality of weighted corrections based on said plurality of corrections and said plurality of weights; and said bid price and/or offer price as a function of said plurality of weighted corrections.

50. An apparatus according to claim 49 wherein at least one of said plurality of weights is time dependent.

51. An apparatus according to any of claims 47 - 50 wherein said plurality of building blocks comprises at least one building block selected from the group consisting of convexity, risk reversal, shift, gearing, Vega profile, and intrinsic value.

52. An apparatus according to any of claims 47-51 wherein said underlying asset comprises a financial asset.