README File for *SigmaFit*™ Version 2

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1. Introduction

SigmaFit^{TM} is one of the results of extensive research in Mathematical Finance and Financial Engineering carried out by Dr. Y. Maghsoodi (*Scinance Analytics*) and it is a direct product of his closed-form solutions of Stochastic Volatility Option Problems. In particular version 2 is based on the closed-form solution to a most advanced of these models.

SigmaFit is a compact PC based Financial Engineering application which within minutes fits Dr. Maghsoodi's Stochastic Volatility (YM_SV)(Futures) Option Pricing Models, to up to 50 (Market) Call option prices, computes Call prices, Put prices, the Greeks and Implied Volatilities at the fit, and allows the user to apply the fitted models to compute prices for options on the asset with other uderlying prices, strike prices, expiries or risk-free rates. This feature is particularly useful in Portfolio Insurance and Risk Management, Hedging and VAR applications. The Black-Scholes (Black-76 Futures) option model is also fitted to data simultaneously by *SigmaFit*. As to date *SigmaFit* version 2 has shown that the YM_SV models can be fitted to and recover real Market prices **up to %6410 more closely than Black-Scholes** or Black-76 Model, and with **Implied Volatility (SMILE) curve matching that of the Market with errors as small as just % 0.27** (see Section 4 and (9.1) below). In addition *SigmaFit* has shown the capability of computing the next day's Market option prices from the day's fitted YM_SV Model **by more than %1114 more closely than Black-Scholes** or Black-76 Model with **Implied Volatility (SMILE) curve matching that of the Market with errors less than just % 0.7.** (see Section 9 below).

Maghsoodi's Stochastic Volatility Models (YM_SV), model the risk-neutral dynamics of the underlying asset S_t and its volatility σ_t at time $0 \leq t \leq T$ as a bivariate system of correlated Stochastic Differential Equations within the following diffusion class and its Jump-Diffusion generalizations:

$$(1.1) \qquad\qquad dS_t = rS_t dt + \sigma_t S_t dw_t$$

$$(1.2) \qquad\qquad d\sigma_t = \mu(t, \sigma_t)dt + \eta(t, \sigma_t)dB_t$$

where r denotes the Risk-Free rate of interest, μ and η denote the drift and diffusion part of the volatility dynamics, and the standard Wiener processes w and B have correlation $0 \leq \rho \leq 1$, i.e. $E\{\Delta w_t, \Delta B_t\} = \rho \Delta t$

For the case of (Diffusion) Futures as underlying asset Maghsoodi modeled the movements of the underlying as :

$$(1.3) \qquad\qquad dF_t = \sigma_t F_t dw_t$$

where F_t denotes the underlying Futures price at time t.

Given the current underlying asset price S_0, the risk free rate of interest r and the time to expiry, within minutes *SigmaFit* fits a member of the above diffusion models (as well as Black-Scholes/Black-76) to up to 50

market European (Futures) Call option prices supplied by the user in a simple two column (strike prices and option prices) text file. It then allows the user to apply the fitted models to compute the asset's European option prices, their Greeks and Implied Volatilities for new sets of parameters and strike prices chosen by the user.

2. System Requirements

SigmaFit may be run under Windows* 95, 98, NT,2000 and XP, and on systems with genuine 486 or Pentium* Processors which are compliant with the IEEE Floating Point Standards, i.e. with the capability of representing double precision floating point reals as large as $1.79 \times 10^{+308}$ and as small as 2.23×10^{-308}, and machine double precision (Epsilon) of 2.22×10^{-16}. Most personal computer systems are compliant with these requirements. The minimum RAM requirement is 32 MB (64 MB recommended).

3. Installation

SigmaFit is dispatched via E-mail as an encrypted and zipped file of 0.5 MB in total. Installation is done by simply unzipping the file and saving the 14 extracted files (0.6 MB in total) into any folder of the user's choice. The Executable files are *SigmaFit.exe* and *SigmaCom.exe* which can be run from within any folder that they have been copied to.

3.a. Demo version

To activate your *SigmaFit* Demo version, simply double click *SigmaFit.exe* from within Windows Explorer*. You can run the Demo version for 30 times (or for 30 days). However, during each run the models can be fitted to data several times. For data other than the default example data sets, the Demo version does not calculate the Put option prices, the Greeks and the implied volatilities, and returns zero values for these, and it cannot use the fitted model to calculate or forecast other options on the same asset, and the output file will be blank in that section.

3.b. Full version

To unlock and activate your *SigmaFit* Full version annual License, double click *SigmaFit.exe* from within Windows Explorer*. The License dialogue box will appear. Record the MID (Machine Identification) and Site code. Click Cancel and repeat this process for *SigmaCom.exe*. E-mail these codes to Dr. Y. Maghsoodi who will in turn E-mail you your password and Init (Initialization) codes for each of these executables. Double click each executable again in turn and enter its Init code in the Init code box of its License dialogue box and proceed by clicking Continue this time. Your annual License is now activated and you will be able to run *SigmaFit* for 365 days by simply double clicking *SigmaFit.exe* each time from within Windows Explorer or from a shortcut and entering your password.

Note that any changes to *SigmaFit* file names or any alterations to your Machine Date will invalidate your License and you will need to purchase a new License. Before **making any adjustments to your Machine Date (or system hard disk recovery, system bios or operating system reinstallations, machine upgrades etc.)** at any time after your initial run of *SigmaFit*, you must first save *SigmaFit.zip* and **remove your License from your machine** by toggling the Scroll-lock key before double clicking each of the executables to invoke the License dialogue box. Enter your correct Init code, select the Remove license option and click Continue. **A Remove code** will appear which you should record for each of the executables. Your License is now removed from the machine. Make all the changes you wish to make

to your system date (or system hard disk recovery, system bios or operating system reinstallations, machine upgrades etc.). Reinstall *SigmaFit* and repeat the initialization steps to obtain the new MID and Site code for each of the executables, E-mail the pair of Remove codes you obtained earlier, the pair of new MIDs and Site codes together with the number of days of your License currently remaining, to Dr. Y. Maghsoodi who will in turn E-mail you a new Init code for each of your executables to run smoothly on your machine's new configuration for the remaining days of your License.

Note that unless you properly remove your License from your machine you will not obtain the correct Remove code and hence not obtain the correct new Init codes to re-run *SigmaFit*. The same procedure applies if you wish to transfer your License to another machine e.g. when upgrading your PC.

Some users may need to increase the number of files and buffers in their system CONFIG.SYS file. There are eight sample Market prices data files. Four of which are 2004 data sets and are added in version 2. F12_0603.TXT, F12_0703.TXT, F09_1712.TXT, F09_1812.TXT (Dec 2002 and Sep 2003 FTSE 100* Futures Option and Strike prices, LIFFE*), CAC9_175.TXT and CAC9_185.TXT (Sep 2004 CAC Index futures, LIFFE*), and S12_0402.TXT and S12_0502.TXT (Dec 2004 S&P 500* Option and Strike prices, CBOE*). In addition to this Readme file there is the LICENSE.DOC file which contains the Terms and Conditions of Use and The Licensing Agreement. Only licensed users can run *SigmaFit* after entering their correct Init code and Password and confirming that they have agreed with The Terms and Conditions of Use and The Licensing Agreement. The user should be aware that interference with files other than the Input Data and Results Files may result in failure and possible permanent corruption of *SigmaFit*.

4. Starting *SigmaFit*

To run *SigmaFit* **simply double-click** *SigmaFit.exe* in its folder within Windows Explorer* or from a Shortcut. *SigmaFit*'s preliminary interface Form will be displayed. Users who do not hold a valid License or do not agree with the License Agreement should click the **NO** button. Users with valid License should enter their Password supplied with their Init codes *SigmaFit* and click the **YES** button to confirm that they have agreed with the License Agreement. Up to three attempts can be made to enter the correct Password after which the Program will end and has to be re-started. Also if the License has expired, after a message the Program will end. Otherwise the Program will continue and *SigmaFit*'s main interface Form will be displayed.

Proceed to entering data in each of the boxes. To obtain a quick tip on each box place the mouse-pointer on that box. In addition each drop-down menu box contains the list of the relevant data for each of the four sample assets, **Sep FTSE* FutDec**, **Dec S&P 500*Feb**, **Dec FTSE* FutMar** and **Sep CAC*FutMay** respectively. Selecting any of these four sample asset names in the top **Asset Name** drop-down menu box will automatically change the contents of all the remaining data boxes in the Form to the corresponding values for that sample asset name, and the Model Fitter will be ready to run. This feature provides additional guidance to users on the type of data needed in each box. The workings of *SigmaFit* is quite simple however beginners may want to run *SigmaFit* for any of these four sample assets to get more familiar with.

Extensive *SigmaFit* version 2 runs have shown that the YM_SV Models can be fitted to and recover real Market prices far more closely than the Black-Scholes and Black-76 models. For example for the four Sample Assets it fitted and recovered real Market prices **more closely than Black-Scholes (or Black-76) model, by %2852, %6410, %4044 and %1652 respectively as well as matching Market Implied Volatilities very closely.** For example for the Dec FTSE FutMar Sample Data, the percentage root mean square (rms) error of YM_SV Model Implied Volatility with that of the Market ($100 \times$ rms error/average Market IV) was

just % 0.27. The same quantity for the IVs of the next day's prices, computed via the YM_SV Model fitted to the previous day's prices was % 0.7. Users may reproduce these results by running the Model Fitter and Price Calculator after selecting any of the four sample asset names within the **Asset Name** drop-down menu.

5. Entering Data

The input data fields in the Form consist of three frames **DATA FOR MODEL FITTER**, **DATA FOR PRICE CALCULATOR** and **Results File Names**. The first frame houses the boxes for entering the option parameters and the name of the file containing European Call option prices to which the models are to be fitted. The second frame houses the boxes for entering the option parameters and the name of the file containing strike prices for which the user requires *SigmaFit* to apply the fitted models to calculate European option prices, their Greeks and Implied Volatilities. The third frame houses two boxes for entering the names of the files which the user wishes *SigmaFit* to create and store the results for the Black-Scholes (Black-76) and Maghsoodi's Stochastic Volatility Models respectively.

The **Futures** box should be ticked if the options underlying asset is Futures rather than plain equity or index. In this case the data provided should be European Call prices of options on Futures, to which a model of the class YM_SV (1.2)-(1.3) above will be fitted together with Black-76 Futures Option Model and comparisons of the fits can be made between the two models.

The **Dividend yield** box is a new feature added in SigmaFit version 2. This allows calculation of options on dividend paying assets. For futures options this box should be left blank. For non-futures options simply enter the annualised percentage dividend paid on the asset which should be within the range [0.0025, 0.30]. For example the annualised dividend yield for the S&P 500 index used in the default data sets is % 1.78 per year hence 0.0178 is entered in the box.

The **Stock/Futures Price** boxes should contain the price of the underlying asset on the Fit Data Date and the Required Date respectively. Any value within the range [1, 30000] can be entered. Obviously the accuracy of the Price Calculator results will also depend on the accuracy of the user's estimate of Stock/Futures price on the **Required Date**.

The **Risk-Free Rate** boxes should contain the risk-free rate of interest on the Fit Data Date and on the Required Date (date for which prices are to be calculated) respectively. Any value within the range [0.0025, 0.30] can be entered.

The **Days to Expiry** boxes should contain the number of days (including weekends and holidays) remaining to the expiry of the option on the Fit Data Date and on the Required Date respectively. Any value within the range [1, 360] can be entered. The smaller the difference of the two **Days to Expiry** values the more accurate the Price Calculator results for the clear reason that the stochastic volatility dynamics may change significantly from day to day.

The **Fit Data File** box should contain the name (up to 12 characters) of an ASCII text file created and saved by the user in the Current (Executables) folder which simply has the strike prices in column 1 and in column 2 (Futures) option prices to which the user wishes to fit the models. The number of rows in the file should be within the range [6, 50], the strike prices within the range [0.5, 50000], and the option prices within the range [0, $Stock/FuturesPrice$] otherwise an error message will appear. The Program will allow the user to rectify the errors. Each of the sample Fit Data Files like F12_0603.txt provide clear examples of the simple format of the Fit Data Files to be created by the user. The data description texts at the bottom of the sample data

files are for information only and will not affect the workings of the Program.

The **Strike Prices File** box should contain the name (up to 12 characters) of an ASCII text file created and saved by the user in the the Current folder containing just one column consisting of the list of the strike prices for which the user wishes *SigmaFit* to calculate option prices using the fitted models. The number of rows should be within the range [1, 50], and as above the strike prices in the range [0.5, 50000].

The **Number of Prices** boxes should simply contain the number of rows in the corresponding data files. These should be within the ranges [6, 50] and [1, 50] in the **Fit Data File** and the **Strike Prices File** respectively.

The **Fit Data Date** is the date of the data to which the models are to be fitted. The **Required Date** is the date for which the user requires prices to be calculated using the fitted models. These dates are for the user's record. The times to expiry are computed independently of these dates from the values in the **Days to Expiry** boxes described above.

The **B-S Results File** box should contain the name of the file (up to 17 characters) which the user wishes *SigmaFit* to create and save (in the Current folder) the option prices, their Greeks and Implied Volatilities using the fitted Black-Scholes (Black-76) Model.

The **S_V Results File** box should contain the name of the file (up to 17 characters) which the user wishes *SigmaFit* to create and save the option prices, their Greeks and Implied Volatilities using the fitted YM Stochastic Volatility Models.

6. Running *SigmaFit*

After entering all the required data in the Form boxes run *SigmaFit* by clicking the **FIT Models to Data** button. A message will appear in the top message box that fitting is under way and may take up to several minutes. Clearly the speed of the execution and the CPU times may depend on how many other programs and applications are running at the same time as *SigmaFit*, as well as the **Number of Prices** to fit and input data consistency. At any time during fitting the Program may be aborted by clicking the **ABORT** button. This action will also delete any of the Results Files if created and will close the Form. The Form's Close button has the same effect. If you wish to run *SigmaFit* again you must double-click *SigmaFit*.exe within Windows Explorer menu again. When fitting to data is complete a message to this effect will appear in the top message box also reporting the percentage of gain in accuracy of fit through using the YM_SV models.

7. The Results Files

When the fitting is successfully completed two new result files will be saved in the current folder under the given Result File Names. These will contain the results based on each of the two models: Black-Scholes (Balck-76) and the YM Stochastic Volatility Models. These files can be viewed in text format using for example Notepad, or you can import, view and save them using Excel* by simply clicking the OLE **View** button next to the desired Results File Name box. An Excel* file should be (saved and) closed before another is opened.

The upper section of each Results File will contain the results computed via the fitted model for the Fit Date, i.e. the results for the option parameters entered in the Model Fitter section of the Form.

The lower section of each result file will contain the results computed via the fitted model for the required date, i.e. the results for the option parameters entered in the Price Calculator section of the Form.

Each file has 10 columns containing respectively the **Strike** prices, **Data** (Market) Call prices, (YM_SV Model) **Call** and **Put** prices, (YM_SV) Call **Greeks** (Delta, Gamma, Rho and Vega) , Data (Market) Implied Volatilities **IV**, and the Model Implied Volatilities **B-S IV** or YM_**S_V IV**. The YM_SV Model Greeks are defined as in the Black-Scholes model, with Vega as the partial derivative of the option price with respect to the initial volatility σ_0.

In the lower section of the Results Files there will be zero entries in the **Data** and **IV** columns since no (Market) option prices were needed for the Price Calculator.

Given a (Market) option price and a set of option parameters, occasionally there may not exist a volatility with which a Model could give rise to that option price. This occurs when the inverse of the Black-Scholes map does not exist at that price. In this case *SigmaFit* returns a value of zero for the Implied Volatility of that price. This has not occurred for the Sample Data.

8. The Re-Run Options

After each successful completion of Fit, the Program remains executable for up to about one hour after which the user should close the Form and start from step 4 above. During the post-Fit executable period three options will be available to the user in the **Re-Run Options** frame. The user may (perpetually) choose to use the fitted YM_SV Model to **Price Other Options** on the same asset. In this case just the parameters of the new European option(s) to be calculated need be entered in the **Data For Price Calculator** frame with just the name of the required results file in the new **S_V Results File** box. Clicking the **GO** button will calculate the required option prices, their Greeks and Implied Volatilities in a new S_V Results File created in the current folder. A new **View** button will also appear to the right of the **S_V Results File** box which the user can click to import, display and save the file within Excel*. The **Price Other Options** feature is not available in **the Demo version** and zeros will result except in the case of the default data sets.

Alternatively the user may wish to fit the models to entirely new set of data and parameters by choosing the **Fit models to other data** option. In this case the **Fit Models to Data** button should be clicked after entering new data as described in step 5 above.

Selecting the **End Program** option followed by clicking the **GO** button will end execution and close the Form. The Results Files will remain saved. To re-run *SigmaFit* the user should re-start from step 4 above.

9. Accuracy of the Results

No doubt different accuracies and speeds of execution may result from execution of *SigmaFit* within different hardware and software environments, depending particularly on the operating system, the processor and the double precision Floating Point representation and capabilities of the particular machine. Other factors are described below.

Accuracy of the Model Fitter

The inverse of the root mean square error of fit is used as the definition of Accuracy of Fit (*AF*). The percentage gain of the YM_SV Models over the B-S (Black-76) Model in Accuracy of Fit is therefore measured by:

$$(9.1) \qquad 100 \times \frac{[YM\_SV\ AF] - [BS(Balck76)\ AF]}{BS(Balck76)\ AF}$$

Obviously the fit accuracy of the Model Fitter can be affected by the accuracy and consistency of the user's

(Market) price data, and by how accurately the entered option parameters (Stock/Futures Price, Risk-Free Rate and Days to Expiry) correspond to the (Market) prices in the Fit Data File. For instance if the Fit Data prices are mid-day quotes the best fit models may be obtained when the price of the underlying used is also the mid-day quote. The fit accuracy of the Model Fitter may increase with the Number of Prices fitted to at the expense of the some CPU time. The evidence from extensive runs with real Market data (see Section 4 above) have shown that within minutes *SigmaFit*'s YM Stochastic Volatility Models can provide very close fits to real Market prices by **up to % 6410 more closely than Black-Scholes or Black-76 Model** and match Market Implied Volatilities as closely as within an average (over the whole curve) of % 0.27 of the actual Market curve.

Accuracy of the Price Calculator

Obviously the accuracy of the Price Calculator results will also depend on the accuracy and consistency of the Fit Data, the Fit option parameters and the accuracy of the (user's estimate of) Stock/Futures price and the Risk-Free Rate on the **Required Date**. *SigmaFit* does not forecast these parameters. It uses the values supplied by the user. The user can expect increases in the accuracy of the Price Calculator for the **Required Date**s which are closer to the **Fit Data Date** (i.e. closer **Days to Expiry** values). The best fit Model's parameters can change significantly from day to day. Indeed the best Price Calculator results may be obtained by using the model fitted to data from an earlier time on the same day. For calculation of opening prices the best Price Calculator results may be obtained by using the model fitted to the closing prices of the previous day. *SigmaFit*'s execution speed combined with automated and real-time quoting systems may provide the user with the power of fitting the YM Stochastic Volatility Models to data as frequently as frequently as the project may require.

The evidence from extensive runs of *SigmaFit* with real Market data has also shown that it can process accurate user supplied data using its fitted YM_SV Model to recover Market prices of other options very closely and far more accurately than Black-Scholes/Black-76. For example using the actual Market price of the underlying and the risk-free rate, *SigmaFit*'s Price Calculator has applied its fitted YM Stochastic Volatility Model and **calculated the next day's Market option prices by over %1114 more closely than Black-76** (Dec FTSE* FutMar sample data) and has matched Market Implied Volatilities with an average (over the whole curve) error of %0.7. Users may reproduce these results by selecting this asset from the **Asset Name** drop-down menu, as described in section 4 above, and running the Model Fitter.

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*Footnotes:**

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Sample Data Files

The sources of Sample Data on S&P 500 Options, FTSE 100 and CAC Index Futures Options distributed with this package are CBOE and LIFFE and these data are distributed with their permission. Permission to perform any action on these data which might infringe the rights of CBOE and LIFFE must be obtained from them.

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