Numerical Analysis in the Financial Industry

A White Paper by Visual Numerics, Inc.
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Introduction

In this era of volatile financial markets, making data-driven decisions based on sound numerical models is necessary for achieving maximum return with minimal risk. While the huge increase in computing power makes it possible to process vast quantities of data, proven and reliable numerical models are needed to enable organizations to analyze, understand and make optimal decisions based on data as well as greater customer, market and competitive trends.

This paper provides an overview of numerical analysis requirements and challenges that are unique to the financial services industry. It also discusses and provides customer examples of how numerical algorithms available in the IMSL® Numerical Libraries and visualization techniques in PV-WAVE® can help address these requirements and challenges.

Analysis Requirements in Financial Services

Numerical Algorithms

Algorithms used for numerical analysis range from basic numerical functions to calculate interest income to advanced functions that offer specialized optimization and forecasting techniques.

Given the broad range of numerical tools available, a financial services provider can develop targeted applications that address specific market needs. For example, quantitative analysts developing financial applications have specialized expertise in their area of analysis. This expertise allows the quantitative analyst to design and develop applications that deliver a competitive advantage for its users. These specialists, however, want to apply their expertise without becoming bogged down in the details of programming every line of code needed for their application and so they desire, and often require, numerical algorithms to embed into their code.

Accuracy and Performance

Accuracy and performance are key requirements for software tools in all industries. In the financial services industry, poor performance or inaccurate results will directly lead to lost capital and lost opportunities. For example, a portfolio optimization application that takes an extremely long time to run might not be frequently updated, resulting in missed market opportunities. Inaccurate results in any financial application can be disastrous resulting in poor decisions, missed opportunities or worse.

With this direct link between accuracy and performance to capital, the choice of software partners is critical when planning financial application development projects. Careful consideration must be given to not only the accuracy and performance today, but what will be required in the future as computing technology continues to evolve.

Software Tool Requirements

There are a number of requirements for software tools that are common across all areas of the financial services industry to help drive the adoption of such tools by groups developing quantitative solutions. These requirements include:

- Improving time-to-market
- Offering a positive return on investment
- Building and maintaining and competitive edge
- Offering multi-platform support such as Windows, UNIX and Linux
- Offering multi-language support such as C/C++, C#/.NET, Java™ and Fortran

Visual Numerics Products Overview

The IMSL Libraries provide users with the software and technical expertise needed to develop and execute scalable numerical analysis applications for the financial industry. The IMSL Libraries save development time by providing pre-written mathematical and statistical algorithms that can be embedded into C, C#/.NET, Java™ and Fortran applications, enhancing return on investment and programmer productivity.

Whether for risk or portfolio management or forecasting and financial modeling, high performance and accurate algorithms can help analysts efficiently and effectively develop applications to manage financial data.

The IMSL C Numerical Library

The IMSL C Numerical Library delivers advanced mathematical and statistical functionality for programmers to embed in C/C++ applications. Using PyIMSL, developers also have the option to write programs in Python that leverage algorithms in the IMSL C Library.

The IMSL C Library is available on a wide range of development platforms and offers functions in key areas such as optimization, data mining, forecasting, and time series analysis. The most recent release of the IMSL C Library includes a Feyman-Kac algorithm for solving **Black-Scholes** problems.

These pre-tested functions result in superior performance, increased scalability, ease of integration and greater reliability for software applications that require mathematics and statistics.

IMSL C# Numerical Library for Microsoft® .NET Applications

The IMSL C# Numerical Library for Microsoft .NET Applications is a numerical analysis library written in 100% C#, providing broad coverage of advanced mathematics and statistics for the .NET Framework. This offers developers using C# or Visual Basic™ .NET (VB.NET) seamless accessibility to analytics capabilities in the most integrated language for the .NET environment with the highest degree of programming productivity and ease of use with Visual Studio™.

The IMSL C# Library is the only numerical library of its kind to offer industry standard numerical analysis and charting for C# and other .NET languages. This Library provides unprecedented

analytic capabilities and the most comprehensive and accessible mathematical, statistical and finance algorithms for C# and VB.NET languages. With the IMSL C# Library, Visual Numerics has brought all of the benefits inherent in the C# and VB.NET languages to a new level by adding robust analytics to its broad set of capabilities.

JMSL™ Numerical Library for Java™ Applications

The JMSL Numerical Library for Java applications is the broadest collection of mathematical, statistical, financial, data mining and charting classes available in pure Java. It is the only Java programming solution that combines integrated charting with the reliable mathematical and statistical functionality of the industry leading IMSL Libraries. This blend of advanced numerical analysis and visualization on the Java platform allows organizations to gain insight into valuable data and share analysis results across the enterprise quickly.

The JMSL Numerical Library provides robust data analysis and visualization technology for the Java platform and a fast, scalable framework for tailored analytical applications. In addition, the JMSL Numerical Library includes optimization algorithms that add to the broad selection of existing data mining, modeling and prediction technologies available across the IMSL Libraries. These optimization algorithms have tremendous potential for businesses by offering the ability to more accurately model real-world financial problems like calculating yields or determining an optimal portfolio.

IMSL Fortran Numerical Library

The IMSL Fortran Numerical Library is the gold standard mathematical and statistical code library for Fortran programmers developing high performance computing applications. The IMSL Fortran Library contains highly accurate and reliable Fortran algorithms with full coverage of mathematics and statistics and complete backward compatibility. The IMSL Fortran Library is a comprehensive library of mathematical and statistical algorithms available in one cohesive package. It combines the powerful and flexible interface features of the Fortran language with the performance benefits of both distributed memory and shared memory multiprocessing architectures.

The IMSL Fortran Library is 100% thread safe, allowing the convenience and performance of multi-threading on selected environments. The IMSL Fortran Library includes algorithms from earlier versions, including the former IMSL F90 Library, the IMSL Fortran 77 Library, and the IMSL parallel processing features.

The PV-WAVE Family of Products

PV-WAVE is an array oriented fourth-generation programming language that can be used by business and financial analysts to build and deploy Visual Data Analysis applications. These applications let users manipulate and visualize complex financial data or extremely large technical datasets to detect and display patterns, trends, anomalies and other vital information.

PV-WAVE allows users to obtain data from multiple sources and offers many options to visualize data. Rapid data analysis and visualization combined with flexibility and power make PV-WAVE the choice among experts.

By increasing productivity, accelerating development and illustrating key knowledge contained in data, PVWAVE gives organizations a competitive advantage.

For users that desire integrated numerical algorithms with data visualization, the PV-WAVE Advantage product includes the IMSL C Library.

Meeting Finance Analysis Challenges with the IMSL Libraries

The IMSL Numerical Libraries address the numerical algorithm and performance and accuracy requirements of the financial services industry from basic financial analysis to the most sophisticated integrated financial services system requirements.

*Popular IMSL Library Algorithms for Finance Include:
Differential Equations: Feyman-Kac for solving Black-Scholes problems
Optimization: Linear, Nonlinear & Quadratic Programming, Genetic Algorithm
Regression: Linear, Nonlinear, Selection, Stepwise
Curve Fitting: Cubic Splines, B-splines, Nonlinear Least Squares, TCB Spline
Simulations: Cumulative Distribution Functions and Random Distributions
Classification: Naïve Bayes, Neural Network
Forecasting: ARMA, Auto_ARIMA, GARCH, Feed Forward Neural Network
Pricing Functions: Bond Pricing, Interest Rate Calculations, Future Value

**A few algorithms are only available in specific IMSL Libraries. Contact Visual Numerics for details.*

Sample Finance Applications

Three common examples from the financial services industry that require numerical algorithms are:

- Portfolio selection
- Option pricing
- Risk management

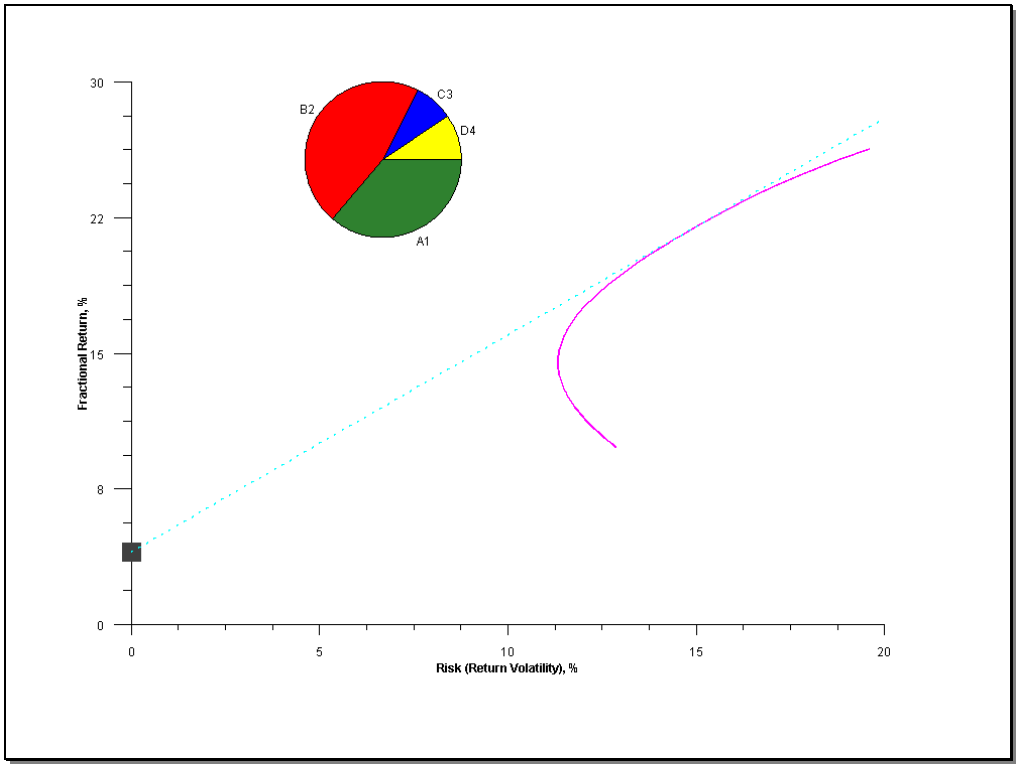
Portfolio Selection

Portfolio selection is a classic optimization application. The basic challenge for this application is to select the portfolio of assets that yields the highest expected return for a given level of risk or minimize the level of risk for a given expected rate of return.

The portfolio optimization problem may be formulated in various ways depending on the selection of the objective function, the definition of the decision variables and the particular constraints underlying the specific situation. Hence, the solution of the portfolio selection problem may involve one of more of the following optimization techniques:

- If the risk of the portfolio can be measured as a ranking of assets or by the linear distance from the target, then the portfolio selection problem can be formulated as a linear programming problem.
- Quadratic programming is applied when the model is a mean variance model.

- Nonlinear programming is applied when the portfolio selection model is characterized by an objective function that seeks to maximize utility as a function of the portfolio composition with the utility function being nonlinear.



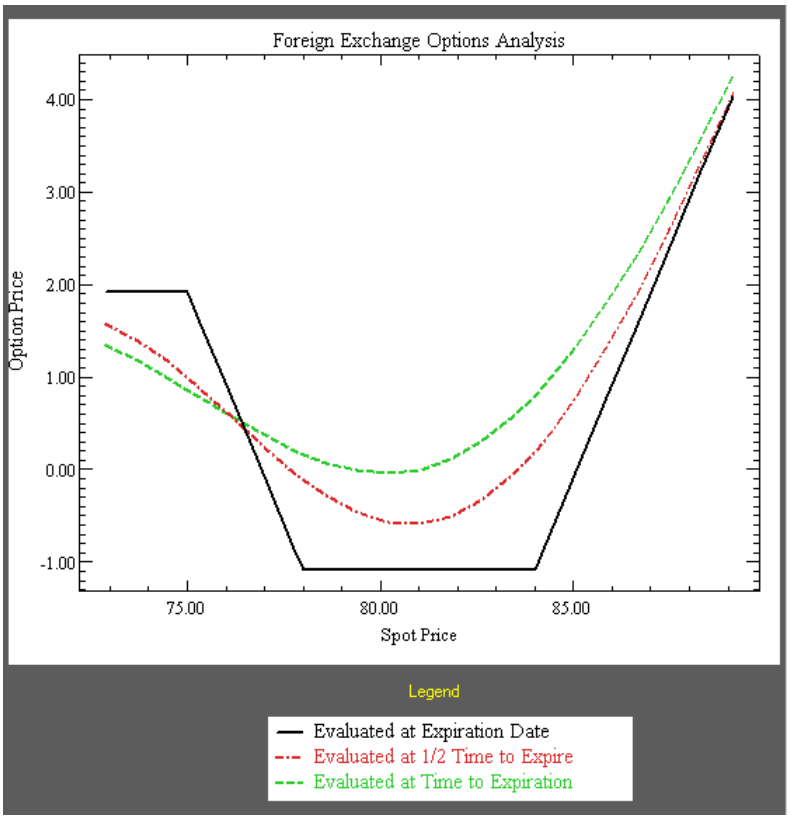
The IMSL Numerical Libraries help asset managers and quantitative analysts develop versatile portfolio optimization applications. Popular techniques used in portfolio optimization include linear, nonlinear, and quadratic programming.

Option Pricing

An options contract is characterized by its expiration date (the date before which the option can be exercised). The pricing of options has been extensively studied and many models have been applied, the most well-known and widely-used being the Black–Scholes option pricing model. Computing the current value of an American call option requires solving the Black-Scholes partial differential equation. The asset may be exercised at any time before its expiration date, thus the numerical computation involves solving a free boundary problem. A finite difference approximation leads to a linear complementary problem with a tridiagonal matrix. Based on a non-negative constrained least-squares (NNLS) algorithm, efficient techniques have been developed for solving a related quadratic programming problem.

A technical white paper that describes the new generalized version of the Feynman-Kac partial differential equation available in the IMSL C Library is available from http://www.vni.com/company/whitepapers. This "Integrating Feynman-Kac Equations Using

Hermite Quintic Finite Elements" white paper describes the Feynman-Kac algorithm in detail and provides many Black-Scholes examples.



This PV-WAVE application compares the Black-Scholes price with the actual market price and shows how much a call option is worth at any given time.

Risk Management

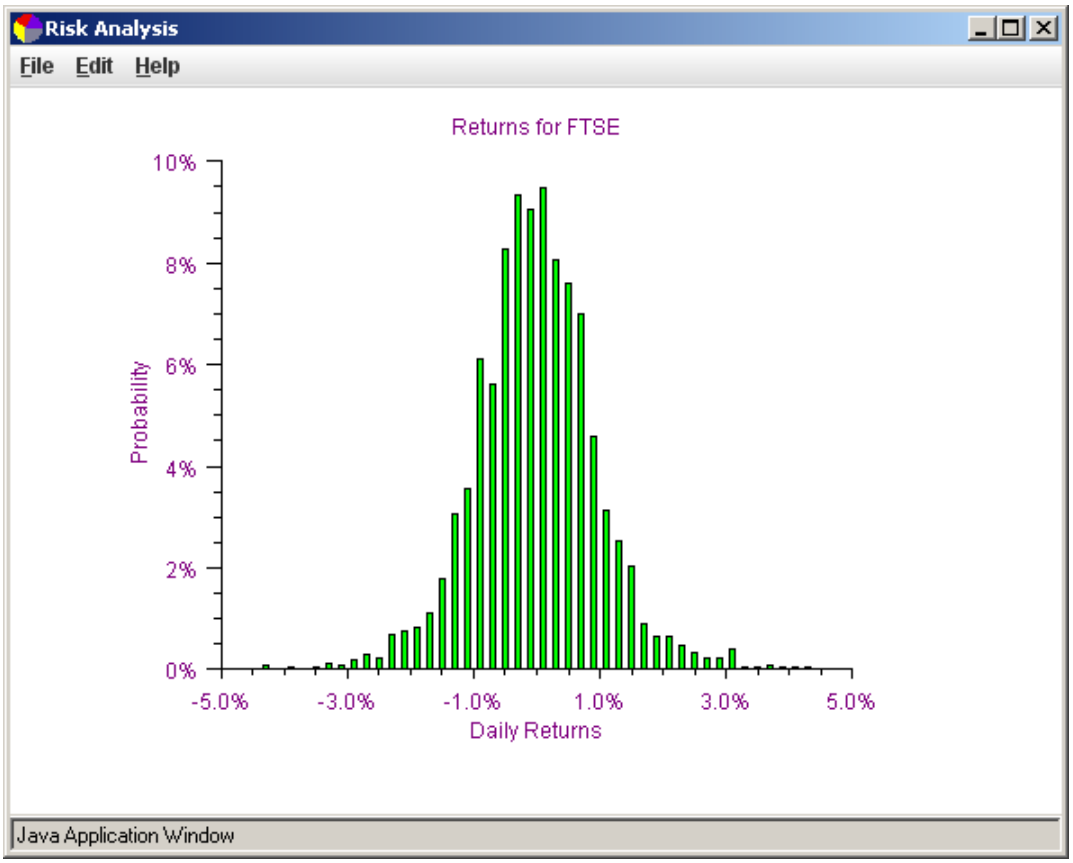
Risk management represents a broad application area of financial optimization. Risk management models are applied to choose portfolios with specified exposure to different risks. Common risks include:

- Interest rate risks
- Liquidity risk
- Credit risk
- Volatility risk

Visual Numerics offers several algorithm classes to address risk management, including:

- Monte Carlo techniques to simulate complex systems, do “what-if” analysis and model the effects of volatity. The IMSL Libraries provide more than 30 random number generators as well as numerous cumulative distributions and variance/covariance functions.

- Time series algorithms for cross-correlation and multi-channel cross-correlation to discover relationships between variables, and model and predict multiple interrelated time-series values.
- Specific time series techniques include ARMA, GARCH and Kalman Filters.
- Many data mining algorithms to help users manage the large volumes of financial data being created and stored today. Classification, data conditioning, association, clustering, modeling and prediction algorithms can all help users identify and hypothesize relationships within data sets.



Monte Carlo simulations are used for modeling uncertainty to help manage business risk and work by replacing uncertain quantities in a model with simulated numbers and then seeing how that uncertainty affects results. The IMSL Numerical Libraries can calculate information about the range of outcomes such as best – and worst-case, the chances of reaching target goals, and the most likely outcomes.

Benefits of the IMSL Libraries

The following sections will provide details on how the IMSL Libraries provide the building blocks to address the analysis requirements and challenges for applications in financial services.

Faster Time-to-Market

Most organizations today do not want to maintain the large, self-contained software development groups that were common in the past. Yet, most organizations have the goal of getting new applications and updates to market as quickly as possible.

The IMSL Libraries help meet this requirement while dealing with the challenge of fewer resources by providing the numerical algorithm "building blocks" needed for financial applications.

The creation of end-user financial applications typically starts with numerical analysis algorithms "building blocks". The robust, reliable and trusted IMSL Libraries are ideal building blocks as they remove the need for the quantitative analysts or other financial professional to write low-level algorithm code and instead concentrate on their area of expertise. Freed from the burden of developing, testing and maintaining the basic building blocks of the application the quantitative analyst is free to explore new or additional financial analysis methods while still quickly creating end user applications. This ability to focus on core competencies is often the difference in a software project that is bogged down by non-application specific details and a project that successfully hits milestones and makes it to completion.

Positive Return on Investment

When developing a financial application, the majority of organizations want to see a positive return on investment (ROI) for the effort put into developing and maintaining the application. Similarly, when making the decision to source algorithms from a third-party like the IMSL Libraries versus developing all components from scratch, organizations again want to see a positive ROI.

In evaluating the build vs. buy decision, there are many reasons why including the IMSL Libraries will offer a positive ROI, including:

- It takes significantly less development time to embed an existing algorithm versus developing one from scratch. Taking into account background research, development, debugging, QA, porting, documentation and maintenance, it's estimated that organizations can reduce algorithm development time from months or even years to just several weeks of effort by embedding an existing algorithm.
- Taking a financial application from prototype to production with the IMSL Libraries is seamless. Developers can write a prototype and the production financial application in the same language (C/C++, C#/NET, Fortran, Java) instead of learning multiple languages, optimizing productivity.

- The IMSL Libraries are seasoned. Since 1970, customers have trusted the IMSL Libraries for their numerical applications and today there are more than 500,000 users worldwide. The libraries are proven to work and offer consistent results across platforms and languages.

IMSL Libraries ROI Scenario

Customer Scenario

- Major financial conglomerate: “Global Financial Corporation” (GFC)
- Uses financial applications on trading floors worldwide
- A typical client portfolio averages US$25M
- By increasing trading efficiencies through its applications, GFC can earn an additional 2%, or $0.5 million, for its clients

Build Versus Buy?

GFC's expertise is instrumental for financial trading requiring various numerical algorithms. One example is the Black-Sholes equation. The "million dollar" question is: "Should GFC build their own numerical routines or buy them?"

Consider the risks:

Direct Costs to Build In-House

- One engineer’s salary and benefits: $100,000
- Researching and developing one algorithm: Estimated effort of eight weeks
- This effort represents approximately $16,000
- $16,000 is the development cost for just one typical algorithm! The IMSL Numerical Libraries contain hundreds of unique algorithms.

Hidden Costs:

- Maintenance
- Porting
- Testing and Quality Assurance
- Documentation

For a typical algorithm, the steps above represent an effort of approximately 16 weeks. A larger, and often riskier, issue is maintenance. If the developer who internally created an algorithm moves to another project or leaves the organization, who will take over to maintain their code? The sum of direct and hidden costs to fully develop a single algorithm can easily exceed $50,000.

The Benefits of Adopting the IMSL Libraries - ROI Summary

- Visual Numerics has invested more than 38 years of expertise in producing the IMSL Numerical Libraries in Fortran, C/C++, C# /.NETand Java.
- Visual Numerics is continually developing, porting, optimizing, testing, and maintaining numerical algorithms for a most accurate, up-to-date performance.
- The IMSL Numerical Libraries include hundreds of algorithms for less than the price as it costs to develop a single algorithm internally.
- When embedding an algorithm from the IMSL Libraries, a developer makes a simple call to a routine, resulting in easy development, no errors and accurate results!

Delivering and Maintaining a Competitive Edge

When evaluating a software tool to use in financial applications, organizations should consider the immediate ROI as outlined in the previous section and should also consider how that tool will help them maintain a competitive edge. In addition to an immediate ROI, using the IMSL Libraries provides ongoing ROI by simplifying the "maintainability" of financial applications. As part of their normal software development process, the IMSL Libraries are regularly tested against new hardware platforms, operating systems and compilers to ensure ongoing compatibility and reducing ongoing software maintenance efforts.

Customers of the IMSL Libraries also get access to new algorithms. The IMSL Libraries are continually being updated and enhanced. For example, in addition to the Feyman-Kac algorithm for solving Black-Scholes problems, IMSL C Library customers also have a new Genetic Algorithm for optimization and a Naive Bayes algorithm for classification.

Organizations can also work with Visual Numerics to customize existing algorithms or build new algorithms to satisfy specific requirements. By working with Visual Numerics Consulting Services, organizations can quickly improve their competitive edge through better algorithm selection or customization or development support.

Multi-platform Support

The IMSL Libraries are tested to run on a wide range of systems, from desktop computers to workstations to the world's most powerful supercomputers. The libraries can be deployed in multiple environments, including clients, servers, databases, or embedded in other applications, including applications deployed across the Internet.

Most importantly, the IMSL Libraries are tested and proven to provide consistent results across platforms. So, regardless of the target platform for a financial application, the IMSL Libraries can be depended on to consistently deliver reliable, robust and trusted solutions.

Multi-language Support

The IMSL Libraries can be used in applications built with standard programming languages such as C/C++, C#/.NET, Fortran and Java™. Using PyIMSL, developers also have the option to write

programs in Python that leverage algorithms in the IMSL C Library. PyIMSL is a collection of Python wrappers to the math and statistical algorithms in the IMSL C Numerical Library.

The IMSL Libraries can also be utilized in applications built with common application development tools such as Visual Basic and Excel. White papers and sample code demonstrating how to access the IMSL Libraries from such tools are available in other white papers on the Visual Numerics website: http://www.vni.com/company/whitepapers

Case Studies

Customer: GFTA (Gesellschaft Fuer Trendanalysen)

Situation:

- The raw materials for GFTA are the masses of data from the world's financial markets. When GFTA was formed in the middle of the 1970s, it began the painstaking exercise of archiving data from the world currency markets. This data was often in the form of daily or weekly information on exchange rates. Since then, the frequency of change in exchange rates has increased enormously and now GFTA is adding several megabytes of market information per day.

Solution:

- The multidiscipline teams at GFTA develop mathematical and statistical models to analyze trends in each market. These models are written in C and C++ using algorithms in the IMSL C Library on powerful servers that run the models every few minutes and send the results to GFTA's desktop systems.

Benefits:

- By adding algorithms from the IMSL C Library, GFTA provided traders with a competitive advantage in the marketplace by equipping them with the most updated analyzed data to work from, thus providing them the ability to make better decisions that can make their organization, and their clients, more money.

Customer: Global Advisors

Situation:

- Global Advisors is a hedge fund offering clients investment management in commodity markets, such as energy and metals. When Global Advisors first launched in 1999, these markets were less algorithmic than today, relying on simple models built in environments such as Visual Basic to analyze market data and deliver trade recommendations to the company's discretionary portfolio managers. These older systems were fairly rigid, which meant if market conditions changed, they did not easily adapt and therefore could produce sub-optimal recommendations to traders. Global Advisors wanted to update their analysis capabilities.

Solution:

- Global Advisors integrated PV-WAVE into their work processes to allow their team to import, manipulate, analyze and visualize data of any size and complexity – with variables

ranging from metals prices to crude oil inventories to temperatures. With the help of Visual Numerics' Consulting Services, the research team developed an application that covers 40-50 commodities and utilizes both linear and non-linear optimization. The application helps identify patterns and opportunities for trading as well as allows Global Advisors to identify possible limitations in their financial models that they would not normally see.

Benefits:

- Using PV-WAVE and working with Visual Numerics consulting services, computation time for Global Advisors' main quantitative trading system has been cut from three hours to a few minutes. This time-savings has allowed Global Advisors to add more sophisticated algorithms to refine results even more and still deliver them to the traders in a timely manner.

Visual Numerics – A Proven Partner for the Financial Industry

Visual Numerics develops leading edge data analysis and visualization solutions for technical, financial and scientific communities worldwide. Visual Numerics' products include the gold-standard IMSL Numerical Libraries, written in C, C#/.NET, Java™ and Fortran, as well as the PV-WAVE Family of products. These products help professionals in the financial industry meet their numerical algorithm, accuracy and performance requirements.

The IMSL Libraries and PV-WAVE also help financial professionals address the challenges they face when developing numerical applications, including:

- Faster time to market
- Ensuring a positive ROI
- Maintaining a competitive edge
- Delivering multi-platform and multi-language support

In addition, Visual Numerics' expert consulting combines technical expertise, decades of hands-on experience and a combination of powerful products to create the highest quality solutions possible for your financial data analysis needs. Visual Numerics partners with its customers to provide advanced analytic solutions and services that are unsurpassed in the industry.