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SOFTWARE REVIEW

IMSL C Numerical Library Version 5.0

By Keith Crowe

Visual Numerics, Inc. has released its fifth major version of the C Numerical Library (CNL), a product available for some ten years now.

My evaluation copy was for NT. Software installation was simple and fairly quick. Installation is a bit more complex now, because of the license manager. But the whole process still took me less than ten minutes. There are subsetting options but I chose to install everything and still used less than 50 MB of disk space. Regardless of ease, no software installation is fun and I appreciate Visual Numerics' efforts to ensure that the process need be visited only once. They do this by providing a set of validation scripts. So you won't discover a botched installation in the middle of your development cycle. The scripts themselves also serve a handy reference to compiling and linking programs with the C libraries.

License management is a new feature for the Intel version of CNL. The management software is the industry standard FLEXlm package from GLOBEtrotter. At first blush the inclusion of a license manager might not seem like much of a "feature" for the user. But unless your goal is to willingly violate license agreements, it really is an improvement because it introduces a lot of run-time flexibility. Suppose you work in a multiplatform shop with a mixture of Unix and Windows operating systems. Simply purchase an appropriate floating license, configure the license manager on a central server, and legally run executables on different environments.

After four major revisions, there is very little in the way of standard numerical and statistical analysis now missing. See table (1) for a listing of high level functional categories. You will notice a bit of overlap in terms of utility functions and some random number generators. This is because C/Math and C/Stat libraries were originally designed to

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AUGUST 2001
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Survey of NAV / Fair Value Practices

In the wake of the problems at Manhattan Investment Fund and at Heartland Advisors and the new SEC guidance on "fair value" pricing for funds, Capital Market Risk Advisors, Inc. (CMRA) conducted an NAV/Fair Value practices survey. Participants included hedge funds, fund of funds, mutual funds and traditional money managers. Perhaps one of the most interesting and concerning findings came from non-participants. When queried as to the reason for their non-participation, a troubling number of potential participants "passed the buck". Some fund managers indicated that their custodian, administrator or third-party pricing services dealt with pricing issues; some administrators declined to participate indicating they followed the policies set up by the funds; and some Fund of Funds disclaimed knowledge of what their funds do regarding pricing issues.

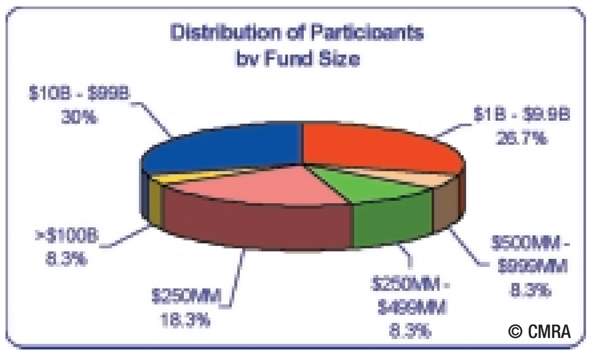
The SEC, ICI and AICPA have recently attempted to clarify guidance on making NAV adjustments for regulated funds; but significantly more work is required to develop a consensus. Several committees have been formed to address the issues for regulated entities, but hedge funds and other non-regulated funds will continue to have great latitude.

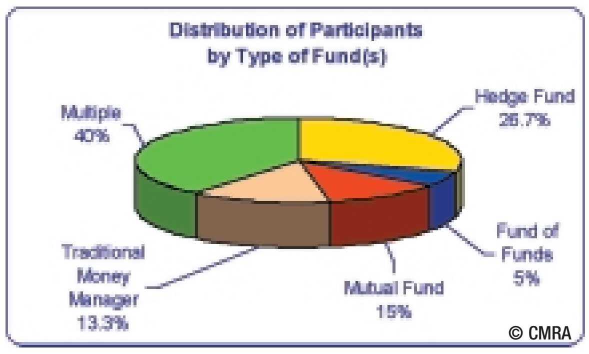
As an example of the potential magnitude of the valuation differences that different pricing approaches create, we reviewed the dealer prices provided for a mortgage hedge fund as of 12/31/00 and found differences between the prices provided by five dealers of CMO's that ranged from 6% to 44%. With these types of price differences, the different methodologies for incorporating dealer quotes can create significantly different results. For example, using the average of the dealer quotes created up to a four-point difference in valuation versus using the "drop the high and low, then average" method.

Consistency of valuation methodologies across funds of similar types and styles is necessary if performance and risk-adjusted performance are truly to be comparable. For example, we found that 22.2% of convertible bond funds make adjustments to NAV of varying sizes and 77.8% do not make any adjustments. Which convertible funds are really outperforming?

Over 60 institutions participated representing approximately $2 trillion in assets. The distribution of participants by type and size were as demonstrated in Figures 1 and 2.

Participants in the survey will receive a detailed, customized peer group analysis. Only this highly summarized version will be available to non-participants.





Figures 1 and 2: Distribution of participants by type and size

Key Findings:

- Overall, only 13% of respondents made adjustments of some kind to the "market" prices they receive from their valuation sources. The most frequently made adjustments are for liquidity and time zone. See Table 1.

Types of Adjustment	% Making Adjustments
Liquidity	6.8
Time Zone	4.2
Size	5.8
Holding Period	0.1
Other Adjustments	1.3

Table 1

- While most respondents indicated that adjustments represented less than 2% of NAV, some indicated that the adjustment in aggregate represented up to 30% of NAV.
- The percentage of participants making adjustments range by instrument from 0% on U.S. Government bonds to 38.7% on warrants and 35.1% on private equity. While U.S. Government bonds are very liquid, one has only to remember back to the illiquidity of off-the-run treasury in the fall of 1998, to question whether a 1x1 market (a market with a $1mm bid and a $1mm offer) for an off-the-run issue is the appropriate "mark" for a $1B position. See Table 2.
- Traditional money managers are more likely than hedge funds or mutual funds to rely on a single dealer quote. See Table 3.
- There is no consistent market practice regarding how dealer quotes are incorporated into valuations. Of the participants who use dealer quotes:

  44% use an average

  27% make a subjective judgment

  18% use the median

  9% drop the high and low, then average

51% of respondents indicated that they marked their long positions to the midpoint of the market versus the more conservative approach of using the bid side. One participant marks to "last trade" and one used "last bid/offer". Overall, practices varied significantly by fund type. See Table 4.

- Shorts versus longs appear to be handled asymmetrically, especially by Traditional Money Managers. See Table 5.
- 93% of overall participants <u>document</u> their pricing policies and the exceptions to policy.
- Of the participants indicating source of valuations, dealer quotes are most frequently used (29.5% of respondents) followed by Bloomberg (24.3%), Reuters (14.2%) and IDC (12.8%). Only 20% of securities are valued based on "other" sources with Merrill being used by 15% of participants for valuing MBS.

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Derivative Pricing—Validation of Results

By Gareth Shaw

Developing software to value derivatives by solving the Black-Scholes partial differential equation is a relatively straightforward task. But if this software will potentially be used frequently by a large number of clients, or as part of a larger modeling problem, perhaps embedded in some other application software, then validation of the results is a vital task, and this can often be considerably more challenging than developing the software itself.

In this article we describe some possible approaches to the question of validation. In particular we focus on methods that aim to verify known mathematical properties of the underlying model. The discussion uses the Black-Scholes equations as an example, but the general principles could be applied to a wide range of application areas.

Theoretical Background

As an example consider the Black-Scholes partial differential equation

$$\frac{\partial f}{\partial t} + (r - q)S\frac{\partial f}{\partial S} + \frac{\sigma^2 S^2}{2}\frac{\partial^2 f}{\partial S^2} = rf, \quad S_{\min} < S < S_{\max}, \quad t_{\min} < t < t_{\max} \qquad (1)$$

for the value S of a European or American put or call stock option, with exercise price X. In equation (1) t is time, S is the stock price, r is the risk free interest rate, q is the continuous dividend, and σ is the stock volatility. The parameters r, q and σ may each be either constant, or functions of time. The quantities of interest are the option value f and the values of various Greeks, which are partial derivatives of f.

It is well known (Hull [3]) that for European options, and American call options with zero dividend q, an analytic solution of (1) is provided by the Black-Scholes formulae [2]. For example, for a European call option the solution is given by:

$$f = Se^{-\hat{q}(T-t)}N(d_1) - Xe^{-\hat{r}(T-t)}N(d_2) \qquad (2)$$

where

$$d_1 = \frac{\ln(S/X) + (\hat{r} - \hat{q} + \bar{\sigma}^2/2)(T-t)}{\bar{\sigma}\sqrt{(T-t)}},$$

$$d_2 = \frac{\ln(S/X) + (\hat{r} - \hat{q} - \bar{\sigma}^2/2)(T-t)}{\bar{\sigma}\sqrt{(T-t)}} = d_1 - \bar{\sigma}\sqrt{(T-t)}$$

$N(x)$ is the cumulative Normal distribution function, and $N'(x)$ is its derivative

$$N(x) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{x} e^{-p^2/2}dp, \quad N'(x) = \frac{1}{\sqrt{2\pi}}e^{-x^2/2}$$

The functions $\hat{q}$, $\hat{r}$, $\hat{\sigma}$ and $\bar{\sigma}$ are average values of q, r and σ over the time to maturity:

$$\hat{q} = \frac{1}{T-t}\int_t^T q(p)dp, \quad \hat{r} = \frac{1}{T-t}\int_t^T r(p)dp,$$

$$\hat{\sigma} = \frac{1}{T-t}\int_t^T \sigma(p)dp, \quad \bar{\sigma} = \left(\frac{1}{T-t}\int_t^T \sigma^2(p)dp\right)^{1/2} \qquad (3)$$

Note that $\bar{\sigma}$ is a second-order average of σ.

A similar analytic solution exists for European put options, or the option may simply be valued using the put-call parity relation. For American call options, and American put options with non-zero dividends there is no such analytic solution and the value must be approximated (for example by the lattice method, or a finite difference scheme).

Case Study

The discussion of validation techniques will use the following suite of software as a case study:

- FD – computes a finite-difference solution of the Black-Scholes equation (1), returning the value of the derivative, as well as values of various Greeks. The time-stepping scheme is a theta-scheme, which includes the forward and backward Euler methods, the Crank-Nicolson scheme, and a range of intermediate methods. The parameters r, q and σ may each be either constant, or functions of time described by values at a sequence of discrete times.

- ANALYTIC – computes an analytic solution of the Black-Scholes equation in the case of European options or American call options with zero dividend. The computation is based on equation (2) and the equivalent formula for European put options. The analytic values of various Greeks are also returned.

- AV – is a utility which computes time-averaged values $\hat{q}$, $\hat{r}$, $\hat{\sigma}$, $\bar{\sigma}$ of q, r and σ as required by ANALYTIC. This is achieved by approximating the integrals in (3) by numerical integration. In cases where the time-dependent functions are known integrable functions of time the exact integrals could be supplied instead of the approximations generated by AV.

General Testing Strategies

The general testing strategy described here is based on the use of *stringent test programs*. These are developed at the same time as the software itself, and are designed to provide a test-bed which can be run on a wide range of different platforms and architectures, with different compilers and options. Detailed results from the stringent test programs can be written to file and compared with base results generated on a different machine, or on the same machine at a different version.

The stringent tests must do the following:

1. Trigger all possible error exits and exceptions generated by the function, and check that the behavior and messages are correct.
2. Check that all input arguments are unchanged by the function in all cases.
3. Exercise as many lines of code as possible. Profiling tools can be used to check the code coverage.
4. Exercise as many potential paths through the code as possible.
5. Check that all special cases and trivial cases produce the correct results, for example a linear equation solver must handle the case of a diagonal matrix or a 1×1 matrix correctly.
6. Run a sequence of realistic test examples. In each case every result of the function must be compared against a result computed by some different method, or alternatively a known mathematical property of the result should be validated. For example, if a numerical integration method is known theoretically to have an error bounded by

$$\|e\| \le \max_{\zeta\in(0,1)}\left|\frac{h^4u^{(4)}(\zeta)}{24}\right|$$

for some function u, then the stringent test program should evaluate the fourth derivative of u and compute the upper bound in order to check that the bound is achieved.

In general the implementation of stages 1–5 are relatively straightforward. The testing of mathematical properties in 6 is the most challenging and interesting part of the process. This is the part that we describe in the next section for the Black-Scholes software.

Validation of the Black-Scholes Software

In the case of the Black-Scholes software the existence of a known analytic solution in certain cases enables us to check the results of the finite-difference solver. However, we also need to validate the results produced by the function that computes this analytic solution. It would be possible simply to re-compute the formula (2) using a different piece of code, but this does not really test any mathematical properties. Instead we prefer to validate that the com-

See Derivative, page 7

GARP Comes Under Attack

In early July, the Global Association of Risk Professionals (GARP) and its founders, Marc Lore and Lev Borodovsky, came under attack from an anonymous source self-described as a "group of financial risk managers" formerly involved in GARP. The attack was contained in an anonymous written document and an anonymous email message signed by one "Doug Adams" (presumably an assumed name for the group).

"Adams" claimed that as a result of the success of GARP's conference, publishing and professional certification programs, GARP began generating "millions of dollars in revenue" and that as a result, Lore and Borodovsky quietly converted the association to a for-profit entity.

To this newspaper, GARP, Lore and Borodovsky acknowledged that GARP is now a for-profit entity. The conversion to this status occurred in November 2000. New York State's Department of State, Division of Corporations confirms that the non-profit entity founded as GARP in 1996 is "Inactive". Though asked, Lore did not disclose the legal name of this entity now functioning as the for-profit version of GARP.

Lore confirmed that GARP and the conference company together grossed approximately $1.8 million while netting approximately $180,000. Of this gross, $1 million was from conference business. "Adams" claims that Lore and Borodovsky personally benefited from GARP revenues at the expense of the association. These claims are not proved and are emphatically denied by Lore and Borodovsky.

Background

GARP was founded in 1996 by Lore and Borodovsky. It quickly grew through a presence of a web site, email newsletters and local volunteer chapters. In March, 2001, GARP claimed almost 16,000 members. Now, GARP claims chapters in 24 countries.

Membership required applicants to be engaged in the financial risk management business or affiliated functions but memberships were free.

Numerous regional directors, local steering committees, global steering committees, and function committees engaged GARP members worldwide, nearly all as volunteers.

Until at least the year 2000, GARP was self-described as a "non-profit, independent organization of financial risk management practitioners and researchers." Now, the word "non-profit" has been removed from the description.

Conversion

Lore states, "In early 1999, a for-profit corporation was created to produce financial risk management conferences for GARP. At the time, GARP did not have the funds to initiate such a costly venture itself. Our goal was to provide the membership with further educational and networking opportunities, while insulating GARP from the risk of loss on an unproven conference business." Borodovsky states the conference company was "was put together with private funds, because GARP could not afford to put it together. Again everyone knew that this is a temporary arrangement to get conferences off the ground. [sic]"

"Once the conferences became successful, it was decided to merge the conference firm with the not-for-profit GARP entity, continued Lore, "However, GARP's original structure did not allow it to merge with a for-profit company. It was therefore necessary for GARP to be temporarily converted into a for-profit entity (which we did in November 2000), then merged with the conference company, and finally converted back to its non-profit status."

Lore told this newspaper that the intention of the for-profit conversion "was to buy the conference company." Borodovsky says the conversion was required because the original "incorporation was improperly done".

We asked Lore, "If these changes were in fact made for the benefit of the association, why were its members not informed until "Adams" came forward." Lore stated, "The organization was never really set up to be a membership driven organization. You'd sign up and be a member of the web site and you'd be able to use the services of the web site. It was never really set up to communicate with the members about what's happening with the organization and that sort of thing."

Transition

GARP has recently announced "an outline of its new corporate governance structure, which will complete its transition back into a not-for-profit organization." From November 2000 until spring 2001, the entity functioned as a for-profit entity. From spring 2001 until now, a transition has been in planning to convert the entity back to non-profit status.

Apparently, the "Adams" claims triggered the mass resignations of senior GARP volunteers and managers. Lore confirmed that GARP CEO, Adam Davids, and the entire seven member advisory board resigned en masse' because "they weren't happy with the way things were being run." Borodovsky claims that the advisory board resigned because they were unhappy that the entity was to become membership driven. He says they were interested in continuing their GARP positions to further their business interests.

GARP states, "Under its final structure, GARP will have not-for-profit 501(c)(6) business league parent organization headquartered in New York [sic]. An interim Board of Directors will be appointed over the next month pending a vote of the membership in the fourth quarter of 2001. Board of Director meeting minutes, full financials and bylaws will all be published on the GARP website upon completion of the transition which is expected to take place over the next 60 days. There will be a subsidiary not-for-profit in the United Kingdom to manage GARP's European business and plans are under way to have a not-for-profit Asian subsidiary as well." Lore says that Bob Mark has agreed to chair the interim Board of Directors.

"I am happy to have achieved our initial aim of devolving the association to its members", said Lore.

Summary

It is now undisputed that GARP was converted from non-profit status to for-profit status without announcement or explanation to the membership generally. It is also undisputed that a transition back to non-profit status is underway. Remaining highly contested are the reasons and purpose (a) for the original conversion to for-profit status, (b) for the en masse' resignation of GARP's CEO and its advisory board and (c) motivating the transition back to not-for-profit status.

Almafin merged with Jaeger & Partner

SunGard Trading and Risk Systems has acquired Almafin, based in St. Gallen, Switzerland, that provides risk and asset/liability management consulting services and software. SunGard has merged this company with its Jaeger & Partner operating unit to form a new operating unit called AlmafinJaeger, a SunGard Company.

Almafin adds complementary consulting and software expertise in risk and asset/liability management to Jaeger. Jaeger & Partner, founded in 1997 and acquired by SunGard in 1998, provides specialized market, credit risk and asset/liability management software and consulting services to private banks and corporations in Switzerland, Liechtenstein and Austria.

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stand-alone. Indeed, if disk space is an issue, separate installation is still an option during setup.

This release fixed several minor, but irritating problems. The installer formerly violated Microsoft Windows implementation standards in a few ways but now conforms well. This is important for some large organizations that require all new software purchases meet certain standards. Another problem I had with earlier versions was Visual Numerics' apparent reluctance to explain just how to get the most out of its top-notch products. The libraries ship with the Math Kernel Library from Intel. There are tremendous performance gains to be realized by configuring and using the MKL on certain hardware platforms. The documentation now describes in full detail how to take advantage of every feature. No more modesty.

The listings in table 1 mask the substantial additions to CNL version 5.0. Most of the new functions fall under C/Stat/Library Random Number Generation and C/Math/Library Special Functions. Of the special functions, virtually all of them are related to finance. Due to constraints on space, the finance functions are what I will concentrate on here.

Whoever designed the interface to the financial functions must have had one eye focused on Microsoft Excel. This was a wise move since VBA, Excel macros and supporting functions are the tool of choice for so much financial analysis. Once simple example is computing asset depreciation using the double declining balance (DDB) method. Assume the following parameter definitions:

Cost is the initial cost of the asset.

Salvage is the value at the end of the depreciation.

Life is the number of periods over which the asset is being depreciated.

Period is the period for which you want to calculate the depreciation.

Factor is the rate at which the balance declines.

The Excel function is DDB(cost,salvage,life,period,factor)

Compare to the CNL equivalent

imsl_f_depreciation_ddb(cost, salvage, life, period, factor)

An example given in the Microsoft Excel documentation for DDB considers an asset purchased for $2,400, having a salvage value of $300 and depreciated over ten years. The ten-year depreciation can be calculated using CNL as follows.

```
#include <stdio.h>
#include "imsl.h"
void main()
{
   float cost = 2400;
   float salvage = 300;
   float factor = 2;
   int life = 10;
   int period;
   float ddb;
   for (period = 1; period <= life; period++)
   {
      ddb = imsl_f_depreciation_ddb (cost,
salvage, life, period, factor);
      printf ("For period %i, ddb =
$%.2f.\n", period, ddb);
   }
}
```

Having the "factor" available can be handy. Here's why. Double declining balance is sometimes called 200 per-

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It Is Time For Lore And Borodovsky's Departure From GARP

It is always hard to take an anonymous attack seriously. It is also easy to discount the content with pejorative descriptions of the claimants. But we need not draw conclusions based upon the "Adams" claims or documents. We can draw our conclusions based solely upon undisputed facts confirmed by the principals.

Following the "Adams" attack, GARP, Lore and Borodovsky themselves acknowledged that GARP had been converted from not-for-profit status to for-profit status. This occurred without announcement or explanation to the membership generally. These facts are undisputed. We also need not draw a conclusion about the motive for this conversion.

We need not conclude whether Lore or Borodovsky personally benefited from the conversion. It is a matter of law that profits of a for-profit entity benefit the select few who are its owners, to the exclusion of all others. This is true whether or not a distribution has occurred. This is true whether or not Lore or Borodovsky are among the owners.

Since November 2000, GARP has continued to act much as it has in the past, looking and feeling like the not-for-profit organization of its past. Volunteers have continued to labor freely to forward the GARP mission, all the while uninformed that the entity had been taken over, on a for-profit basis, by some select few.

Lore and Borodovsky now offer an explanation for these events. Yet the fact that this conversion occurred without announcement or explanation to the membership is offensive.

While Lore claims happiness over now "devolving the association to its members", it is unlikely that many of the members even suspected that the association wasn't in their hands all the while. In fact, hundreds if not thousands of people volunteered for GARP's mission. Now Lore tells us that even those contributions did not earn the membership the right to know that such a major change had occurred or why it had changed. What other information has not come forward?

Lore and Borodovsky deserve the thanks of financial risk managers worldwide for founding GARP and operating it until last year and we bear them no ill will.

Yet, the entity was converted to for-profit status without an announcement or explanation to the membership. Lore and Borodovsky are responsible for this conversion. As a result, Lore and Borodovsky should no longer maintain the confidence of the global association's membership; it is time for Lore and Borodovsky to leave GARP. An international trade association cannot be run in this manner without challenging the principals who so conduct themselves. This is so, whether the principals actually enriched themselves or not.

One might now claim that there was never an "association", that there was merely the appearance of one. However, worldwide, thousands of people have confirmed the demand and need for such an association.

GARP can be that association if Lore and Borodovsky set aside their personal interests and give that organization to the people who really make it what it is. Only when they are gone from GARP will GARP achieve the greatness its thousands of members and volunteers reach for daily.

Survey *CONTINUED*

- Practices vary widely but when adjustments are made, the most common methods are based on:
  - Flat % write-downs
  - Volume related write-downs
  - Judgment
  - Float
- Definitions of "illiquid" vary across participants and include:
  - >10% ownership
  - Zero or one market marker
  - No price change for five consecutive business days
  - Cannot sell position in one week at 1/3 daily volume
  - Not able to be sold at the current value, within seven days
- When NAV is adjusted based on time zone, a wide variety of methods are used:
  - Adjust all "relevant" prices to NY close
  - Adjust cross exchanges trades to same time
  - Adjust to futures close in each local market
  - 4pm NY time
  - "Fair value pricing" adjustments
  - All prices taken at 5:45 Paris time
  - Closing prices the day before
  - Adjust to futures close in each local market
- There is a wide range of methods cited for pricing more complex instruments:
  - Matrix pricing
  - Interpolation
  - OTC options valued at in-the-money amount
  - Parity calculations
  - General partner valuations

	% Making Adjustments						
	Liquidity	Time Zone	Size	Holding Period	Held at Cost	Other	Total
Warrants	9.7	14.5				14.5	38.7
Private Equity	24.3					10.8	35.1
Private Placements	20.3		4.7			7.8	32.8
Convertible Bonds	9.5					12.7	22.2
CLOs/CBOs	17.2						17.2
Other ABS	13.0						13.0
OTC Options		5.5	5.4				10.9
Emerging Market Debt & Equity	10.5						10.5
FX Forwards	5.2	5.2					10.4
Swaps		10.0					10.0
MBS	9.7						9.7
Equities		7.1		2.4			9.5
Exchange Traded Futures & Options	1.3	7.6					8.9
Corporate Bonds Publicly Traded	3.4				1.1	1.1	5.6
Government Bonds							0.0
Average Total	**11.3**	**8.3**	**5.1**	**2.4**	**1.1**	**9.4**	

Table 2

	% Marked at Midpoint	
	Longs	Shorts
Overall	43	53
Traditional Money Managers	17	67
Fund of Funds	67	50
Hedge Funds	64	73
Mutual Funds	38	40

Table 5

	% Willing to Rely on One Quote
Traditional Money Managers	75.0
Hedge Funds	63.6
Mutual Funds	37.5

Table 3

	% Marking to Midpoint
Fund of Funds	67
Hedge Funds	60
Mutual Funds	38
Traditional Money Managers	17

Table 4

CMRA (www.cmra.com) *was founded by Leslie Rahl, a leading expert in derivatives and risk management with almost 30 years of experience in the Financial Services industry. CMRA offers practical solutions honed by the experience of servicing more than 175 clients on six continents in the last decade. Leslie Rahl can be reached at (212) 404-6101, fax (212) 404-6110 or* e-mail lrahl@cmra.com.

Internal Market Risk Model Approved By Italian Central Bank

Banca Commerciale Italiana (BCI) recently received approval from the Bank of Italy for the use of internal market risk models using a variety of Value-at-Risk (VaR) methods, including parametric methods and Monte Carlo simulations for non-linear portfolios. The models are built with Algorithmicís Algo Suite at their core and provide actionable risk information to many business areas of the bank. The approval marks the first time that an Italian bank had an internal model validated for use by the central bank.

As a consequence of the recent merger of BCI with Banca Intesa, the approved model will be extended to estimate regulatory and economic risk capital for the combined operations of the new IntesaBci bank, which will be Italy's largest bank.

"We believe that the standard regulatory models for market risk do not correctly reflect the actual economic risk capital needs of sophisticated banks such as IntesaBci and result in onerous capital requirements. Using Algo Market, we have developed an internal model that produces far more accurate risk reports and delivers tremendous capital savings," said Mauro Maccarinelli, Head, Risk Management, Capital Markets at IntesaBci.

The models approved cover market and equity-specific risk, and will cover credit risk when the use of internal models for calculating spread and event risk are approved by the Bank of Italy, expected within a year."

The bank is also well on its way to being able to model all of its credit derivatives' activity, which is important given IntesaBci's status as a player in the credit derivatives arena. Current internal procedures help the bank know its exposures for a large segment of the firm's credit derivatives portfolio in VaR terms.

IMSL *CONTINUED*

cent declining balance. Note that a factor of 2 produces the standard DDB. There is a variation of DDB called 150 percent declining balance that uses 150 percent of the straight-line annual percentage rate. So if a user needs this computation, he can simply set factor to 1.5 in imsl_f_depreciation_ddb.

Version 5.0 provides many other basic financial functions too, such as present and future values, cumulative interest and principal, effective rates and so forth. Also included is a section called "Bond Functions" with tools for evaluating such things as the number of days in a coupon period, bond equivalent yield of a T-bill, etc.

Included among the dozens of new interfaces is support for contingency analysis using duration and convexity. These tools quantify the sensitivity of securities to interest rate shifts. There are of course standard formulas used for calculating these quantities, in materials published by the SIA and others. Nonetheless here you have computational problems that, in theory at least, could be lifted straight from calculus textbooks and solutions provided by mathematical software experts. I find that comforting.

Taking a duration example from the documentation, we can see how the designers at Visual Numerics implemented these concepts. Here, imsl_f_duration computes the annual duration of a security with the settlement date of July 1, 1995, and maturity date of July 1, 2005, using the Actual/365 day count method.

As in the case of the struct tm, you will generally find that CNL makes good use of existing standard structures. I'm sure there was a temptation to introduce a new date format. Although a new structure might have been "prettier", resisting the inclination to bulk up the API was a good choice.

```
#include <stdio.h>
#include "imsl.h"
void main()
{
struct tm settlement, maturity;
float coupon = .075;
float yield = .09;
int frequency = IMSL_SEMIANNUAL;
int basis = IMSL_DAY_CNT_BASIS_ACTUAL365;
float duration;

settlement.tm_year = 95;
settlement.tm_mon = 6;
settlement.tm_mday = 1;
maturity.tm_year = 105; maturity.tm_mon = 6; maturity.tm_mday = 1;

duration = imsl_f_duration (settlement, maturity, coupon, yield, frequency, basis);
printf ("The annual duration of the bond with ");
printf ("semiannual interest payments is %.4f.\n", duration);
}
```

In a review of the last major version of CNL, I remarked that only a little incremental value had been added. I certainly cannot make that same complaint this time. I expect the libraries to find their way into many new applications with the financial functions introduced in this release. I make this claim because version with 5.0 its cheaper to reimplement front office, Excel applications in C. And that is significant because once in a language like C, high-performance, cross-platform custom apps and web front-ends are just a step away.

Table 1.

C/Math/Library

- Linear Systems
- Eigensystem Analysis
- Interpolation and Approximation
- Quadrature
- Differential Equations
- Transforms
- Nonlinear Optimization
- Special Functions and Financial Functions
- Statistics and Random Number Generation
- Printing Functions
- Utilities

C/Stat/Library

- Basic Statistics
- Regression
- Correlation and Covariance
- Analysis of Variance
- Categorical and Discrete Data Analysis
- Nonparametric Statistics
- Tests of Goodness of Fit
- Time Series and Forecasting
- Multivariate Analysis
- Survival Analysis
- Probability Distribution Functions and Inverses
- Random Number Generation
- Printing Functions
- Utilities

puted analytic solution satisfies the partial differential equation (1). To do this it is necessary to compute derivatives of the analytic solution returned. This can be achieved by returning to the fundamental definitions of derivatives from calculus

$$\left.\frac{\partial f}{\partial S}\right|_{(S,t)} = \lim_{\delta S\to 0}\frac{f(S+\delta S,t)-f(S,t)}{\delta S}, \quad \left.\frac{\partial f}{\partial S}\right|_{(S,t)} = \lim_{\delta t\to 0}\frac{f(S,t+\delta t)-f(S,t)}{\delta t} \qquad (4)$$

So for a sequence of random points within the (S,t) domain the following test is carried out. The analytic solution is computed using ANALYTIC at the chosen point, and also at a neighboring point perturbed by a very small displacement in the S direction. Using these values in (4) the derivative with respect to S is calculated. This is then compared against the analytic expression returned from ANALYTIC for the Greek:

$$\Delta = \frac{\partial f}{\partial S} = e^{-\hat{q}(T-t)}N(d_1) + \frac{Se^{-\hat{q}(T-t)}N'(d_1) - Xe^{-\hat{r}(T-t)}N'(d_2)}{\bar{\sigma}S\sqrt{T-t}}$$

which can be obtained by differentiation of (2). By perturbing also in the t direction and applying equation (4) the stringent test program also validates the other Greeks calculated by ANALYTIC

$$\Gamma = \frac{\partial^2 f}{\partial S^2}, \quad \Theta = \frac{\partial f}{\partial S}, \quad \Lambda = \frac{\partial f}{\partial \sigma}, \quad \rho = \frac{\partial f}{\partial r}$$

Note that for Λ and ρ the process is slightly different. In these cases the perturbations are made to the parameters σ and r, rather than S and t. However, the principle is the same. Having validated all the Greeks it remains to check that the analytic solution satisfies the partial differential equation (1). This is done by checking that f satisfies:

$$\Theta + (r-q)S\Delta + \frac{\sigma^2 S^2}{2}\Gamma = rf,$$

which is simply a restatement of (1) using the Greeks.

This validation of ANALYTIC is carried out for various types of options and other variations in the input arguments. In addition the stringent program checks that the boundary conditions are correctly satisfied.

In the case of time-varying values of q, r and σ it is also necessary to validate the functioning of AV, which evaluates the average values defined in (3) and required in (2). Because of the numerical integration used internally by AV we know that the results for the first-order averages should be exact for all cubic polynomials. So the stringent test program for this routine tests the results for constant, linear, quadratic and cubic basis functions. The second-order average is only exact for linear functions, so this is tested for constant and linear basis functions.

Having validated the analytic solver the stringent test program proceeds to test the finite-difference method FD. Since this is an approximate method the results will not be exact, but should converge towards the analytic solution as the time-step and mesh size are reduced [5]. For all choices of time-stepping scheme the error in the option value and Greeks should decrease by a factor of at least half when the mesh and time-step are both halved. This shows that the error is at least first order in both S and t. To test this the finite-difference function is called repeatedly on a sequence of meshes of increasing refinement. On each mesh the error norm for f and all the Greeks is computed using the analytic solution. After completion of the sequence of refinements the convergence property is validated.

In cases where the analytic solution is not valid the results of FD are compared in a similar way against the analytic approximation of Macmillan/Barone-Adesi and Whaley [1].

Experience with this Approach

The validation procedures described here were applied by the Numerical Algorithms Group to a new suite of Black-Scholes routines developed for Mark 20 of its Numerical Library [4]. The stringent test program was developed in parallel with the software itself, and new tests were added to the stringent program as new functionality was added to the source code. The resulting early error detection helped to accelerate the development process. Despite careful evaluation of the mathematical expressions for the option value and Greeks, and careful programming of the source code, mistakes were still made, detected by the stringent test program, and corrected.

The code will now be implemented on a wide range of different platforms, and will form the basis of related functions for the NAG C Library. The stringent test program will provide a vital check of the correctness of all these implementations.

Gareth Shaw works for the Numerical Algorithms Group, which creates components and other software used by most of the major finance houses in the world. Questions can be forwarded to him via infodesk@nag.com

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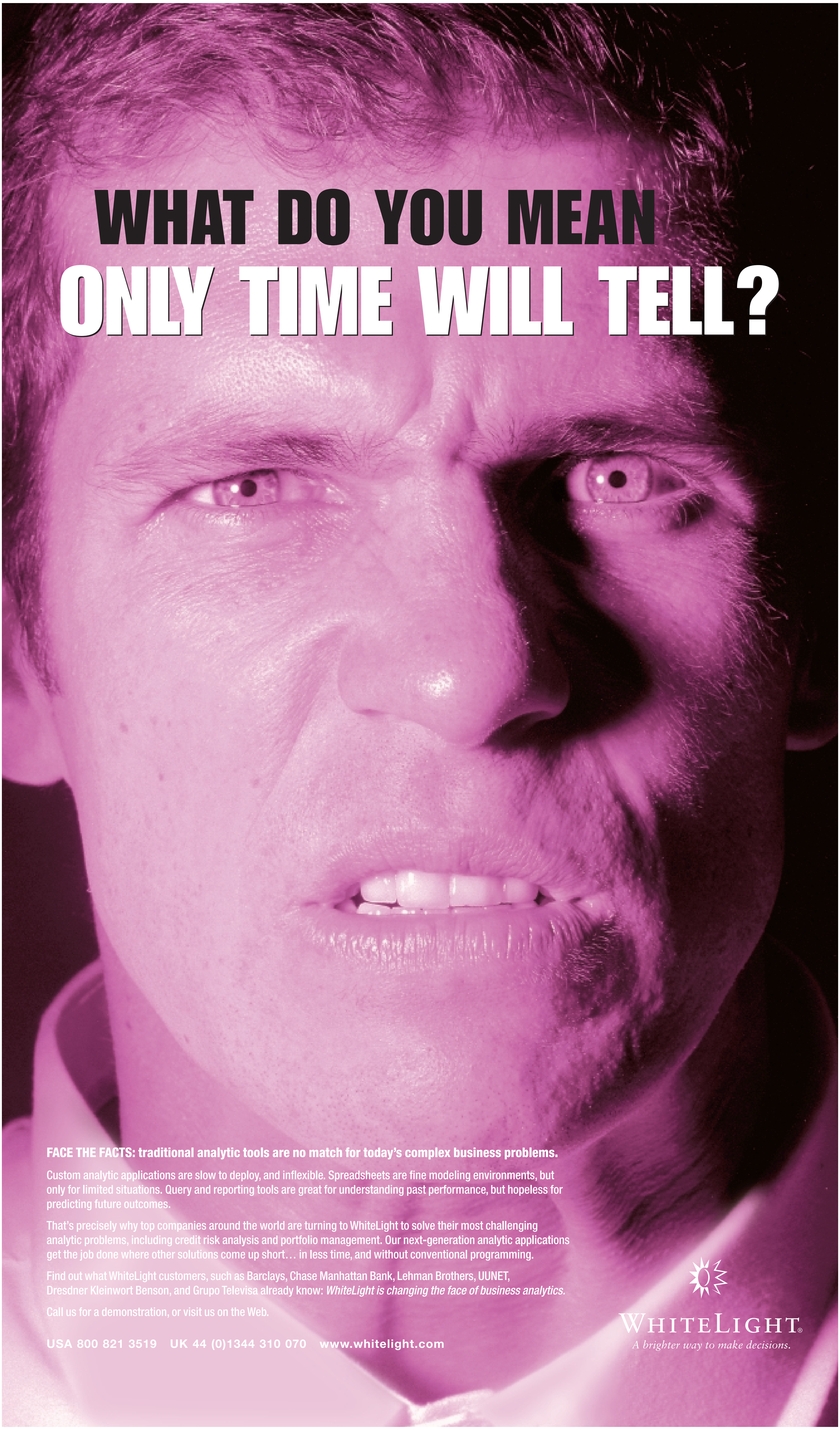

WHAT DO YOU MEAN
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FACE THE FACTS: traditional analytic tools are no match for today's complex business problems.
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