In a global arena, where free market enterprise spawns demand for new financial securities, and investment process, **Investment Technology** has often led to fundamental changes in capital markets.

As the power and speed of computing systems and the sophistication of software increases, mathematics can be more broadly applied in the search for market anomalies.

Although markets appear chaotic and random, in contrast to purely economic observation, scientific analysis can consistently support innovative participants to acquire market advantages, manage risk more effectively, and generate superior returns.

Advanced Research Concepts (UK) Limited
Victory House
London

Summary

ARC has pioneered, in collaboration with research at Imperial College, London, the development of **Artificial Intelligence** to solve problems of financial markets trading. The work has been evolving since 1990 and in the last four years, significant progress has been made.

ARC's most rapid and successful advances have occurred in the areas of Foreign Exchange and Interest Rate forecasting and trading systems. We have acquired substantial experience in using Neural Networks and other AI tools as part of these systems.

Our research has been disseminated world-wide including extensive collaboration with various universities, and numbers of leading international investment banks.

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Integrating Mathematical Tools Into Financial Markets

Financial Markets

All participants in a financial market are seeking a profit. They may determine their profits in different ways but market equilibrium is determined by a balance between these varying motivations. Since no one participant can always be right it is necessary to accept losses within the process of making gains. Otherwise the cost of trying to always be right will eliminate eventual gains.

The volume of information about the capital markets continues to increase and this necessitates the need for additional, faster tools. Analysis must be achieved more quickly for time and information arbitrage to occur. The market participant must be aware of the time value of information. This time value diminishes as new information is generated. The implication of this is that information access and interpretation is time critical. Initially a small volume of highly valuable information is available. With time and as more information becomes known, its value decreases.

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Financial Engineering

Financial engineers seek to uncover profit opportunities whilst minimising (not eliminating) risk. These opportunities may then be exploited by products the financial engineers create. Every trade made incurs a risk, is a roll of the dice, and this risk must be managed. The field of risk management and hedging attempts to address this issue. The approach taken is that any means which can control and systematically determine a loss results in maximising profit. Risk must be accepted and understood. Speed and efficiency dominate this process.

Risk Management

Clearly, a systematic accounting of risk and the factors affecting price change would not only increase the time available for intuitive analysis, but also could then potentially be used as a forecasting model input. We have determined that if a systematic risk model is deployed to react dynamically to changes in risk, even while constrained by quality judgements or portfolio limits, its output can improve the potential of our forecasting models by more than the quality of conventional forecasting inputs. In other words, we have observed that volatility (i.e. risk) adds specific value to our forecasting models.

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Forecasting

Our key objective is to maintain a consistent approach to forecasting and the use of predictive models. We apply and follow three principals:

1.) The *performance* of forecasting and predictive models change over time.

2.) Rather than use absolute values, we use *risk* to define model output quality.

3.) Combining different forecasting model outputs reduces uncertainty and risk, while increasing performance quality. (Classic diversification principle).

Foreign Exchange Forecasting
(A Case Study)

Introduction

The following pages outline the dimensions of the ARC FX model, now in operation, which has evolved from the basic tenants and discoveries of our research related to foreign exchange markets. We are knowledgeable about a variety of conventional data analysis and forecasting models, such as statistical, time series, pattern recognition and classification, linear and non-linear curve fitting concluding that each has its own specific value. As mentioned, for a number of years we have included in our investigations, generalised forecasting methods, which may, but only by implication replicate some of the characteristics found in models based on specifics. Interrelating specific and generalised models has improved the overall quality of forecast output.

For example, a neural network is a generalised method. What goes on inside a neural network is essentially unknown, because of the complexity of its iterative environment and mathematical dynamics. It is more profound to accept the concept in terms of the value of output, than to attempt to reduce the works to a formula, which cannot increase that value. Run in conjunction with more conventional models, the output is measurably of higher quality.

Much of our research has concentrated on the value of outcome across a variety of models to form a consensus as to input variables. Due to the nature of these tools, an ongoing requirement exists to continue with research simply because the markets and models are dynamic. Using formal mathematical methods, we have selected the input variables for use with a neural network to forecast Foreign Exchange rates.

The limitations of the neural network are essentially human. More than a basic software implementation is necessary for successful operation. One should not underestimate the need for experience in this area to assure a high level of quality output. Practise, not procedure must be emphasised. Time and commitment are required to keep up with the changes in computational neural technology. The value of cumulative experience over time has involved years of work.

FX Process Description:

A. The Forecasting Process

B. Model Processing

C. Trading Model Selection

D. Summary - The Overall Processing Cycle

Model Processing

Daily

The procedure for daily foreign exchange forecasting encompasses the following steps:

(1) select a 'closing' rate time (e.g. 4:00 or 4:30 p.m. London, 3:30 p.m. New York, 11:00 a.m. London Fixing)

(2) Input closing rates for each currency:

   (a) spot
   (b) 30-day, 90-day forward rates
   (c) overnight interest rates
   (d) 30-day, 90-day LIBOR rates
   (e) other indicators including volatility data

(3) Run Forecasting Tools

(4) Run Trading Models

Trading Model Selection

Trading Model Output

(1) A user may pre-select any one or all of our trading models to generate specific daily Buy/Hold/Sell signals.

(2) Where a user selects one model, ARC will continuously run all models to maintain historic relative performance comparisons such that the user can be notified of different performance results as influenced by trading signal logic.

(3) Trading signal model choice needs to be consistently reviewed in order to maximise the benefit of model switching.

(4) Trading performance risk (covariance matrix) is based on model risk. Each 'model' is considered 'a trader' and its performance (risk) is used to assess position/trading risk measurement using Risk Measurements Unit (RMU's).

The Overall Processing Cycle

Example of typical processing Phases:

PHASE - I Forecasting Tools • used to generate a Forecast	PHASE - II Trading Models • used to generate a Trading signal	PHASE - III Performance Measures and Attribution Reporting
• Algorithms are used to forecast and predict FX-rate, interest rate or futures prices and movements. Algorithms can include: - Neural Networks (t+1 to t+3 days) - Parametric Risk Trade-off Models - Market Models based on Technical Analysis	• Algorithms are used that determine when to: - Buy - Hold - Sell • The Trading Models incorporate turning point logic, rate of change logic and other market timing techniques.	• Reporting tools that look at: - daily - monthly - quarterly - annual performance of Trading Models as to P/L, Income Attribution, Model Risk and Performance Attribution, including Position Risk and Exposure.

Projects Undertaken

Japanese Securities House	Global Securities trading price database for support of 12,000 international securities traded between London, NY and Tokyo offices.
Leading French Broker (and subsidiaries)	Reporting equity research, Buy/Sell recommendations to French clients.
French Fund Manager	Investment management technology strategy, including design and installation of systems.
UK Bank - Investment Management Division	Japanese Warrants Trading System developed with installation in London, Tokyo and Hong Kong.
UK Commercial Bank	Group-wide risk management system, price database and risk analytics for investment management operations.
US Commercial Bank	Systems support for proprietary real-time foreign exchange tick data analytic process. Includes historical archiving of tick data for over 20 traded currencies supporting world-wide foreign exchange trading operations from London.
US Investment Bank	Co-authored proprietary trading method and system for European equities between London and New York operations.
Large Swiss Bank	Development of a world-wide market price database and analytics.
UK Bank -	

Interest Rate/Equity Options	Fixed Income trading support Trading System including all front-end dealer enquiry facilities and integration of derivatives trading and pricing system.
UK Commercial Bank	Currency Options pricing and Hong Kong, New York, London risk management system for FX Division London interbank currency options trading and spot dealing operations.
German Bank	Group-wide operating strategy and systems implementation for futures, options and bond trading.
US Investment Bank Trading Division	Intermarket equity and fixed Global Program income basket arbitrage trading system with primary trading operations in Tokyo, New York and London.

Other Projects, by Similarity of Project

Development of capital and risk analytical and reporting systems for foreign exchange and fixed income trading for five major institutions in London, Paris, Frankfurt and Munich.

Technical development and implementation of neural network and sophisticated optimisation software for clients in London, Zurich, Paris, Frankfurt, Milan, and Edinburgh.

Principal Directors
Advanced Research Concepts (UK) Ltd.

Henry Livingston, Executive Director, is responsible for ARC's commercial direction. With twenty years as a global fund manager in New York and London, he developed a number of innovative investment processes with proven and successful multi-year results. More recently he has been involved in product development, marketing and the management of investment companies.

In 1986, he established an international fund management subsidiary in London for Kidder Peabody, a broker/dealer, and was hired two years later by USF&G, a large American insurance company, in a similar capacity. With outside owners, he formed a London based futures fund management group in 1989, serving as a founding director until 1992.

He has been a registered representative of the NYSE, a member of IMRO and SFA, currently sits on the board of several US and UK companies and is a principal in ARC with Dr. Green.

Henry Green, PhD, Research Director, has more than ten years of academic and financial experience employed by and consulting to industrial and financial institutions. His primary responsibility involves developing and implementing investment systems which use advanced mathematical concepts and quantitative risk management techniques.

In 1989, with other principals, he formed Financial Technology Systems Development, Ltd. (FTSD), which offers a variety of investment technology applications using Citibank's FAME Software, and now has North America, European and Far East financial organisations as clients. In 1993, he formed ARC to develop and offer systematic, proprietary investment strategies.

A summary list of projects in the area of mathematical and systems programming Dr. Green has undertaken and completed is attached. The noted work has been undertaken both as a consultant and through FTSD.