# Chapter 2

# Computer-based Technology In the Finance Domain

## 2.0 Overview

This chapter introduces the key issues for the application of computer-based technology in finance. It reviews the challenges faced and concludes with the need for a paradigm shift at the computational level to meet the wider agenda for computing in finance.

Section 2.1 considers key issues for the application of computer-based technology in finance at the institutional (integration), market (support of the shift from old to new trading model), and investment levels (support of the finance research development cycle and the group financial engineering activity). Section 2.2 highlights technical and strategic demands for a wider agenda for computing capable of addressing the key issues addressed in section 2.1. Challenges facing prevalent tools and technologies in delivering solutions to problems in the finance domain are overviewed. Section 2.3 concludes with the need for a paradigm shift in computing to address the key issues of the application of computer-based technology in finance at the institutional, market, and investment levels.

# 2.1 The Key Issues of the Application of Computer-based Technology in Finance

Computer-based technology is becoming an integral part of almost every industry including the financial one. An appropriate use of computer-based technology is a critical success factor at the micro and macro economic levels. The uses and applications of computer-based technology vary across and within industries. This motivates the investigation of the application of computer-based technology in each and every industry and the focus on its diverse applications within a particular industry.

This thesis focuses on the uses and applications of computer-based technology in the finance domain. The key issues of the application of computer-based technology in finance are considered at the institutional (in the financial enterprise), market, and investment levels.

## 2.1.1 Application of Computer-based Technology in the Financial Enterprise

> *A financial enterprise is mainly a financial intermediary that facilitates the transfer of funds from entities in financial surplus to entities in financial deficit. Financial intermediaries include brokerage firms, banks, stock exchanges, and financial institutions offering trading clearing, or investment services. Appendix 2.1 overviews the organisational structure of typical financial intermediaries.*

The key issues of the application of computer-based technology in the financial enterprise, identified in this thesis, are centred around *integration*. All aspects of integration are needed to face competition in a global market, namely software integration, devices integration, the integration of human and computing activities, and the coherent integration of computer mediated group social activities.

### 2.1.1.1 Software Integration

The software industry has seen tremendous progress over the last decade. A diversity of tools serving various needs in different industries have been produced. Tools developed for the financial industry are numerous. Some are special purpose financial tools, while others are general purpose tools used in the broad business sector. Although different tools exist separately, success in the financial industry relies on an integrated suite of tools. To meet this requirement, some service providers offer a suite of tools satisfying various needs in the financial enterprise, in the financial market, and for investment. However, software integration needs remain unfulfilled with a wide range of available tools having different underlying technologies and diverse functionality.

It is difficult to make a proper classification of tools used in the financial industry. Many general purpose business tools are suited for tasks in the financial enterprise. Bocij (et al, 1999) divides business tools into two broad categories: tools that support an organisation's business activities (process control, transaction processing, communication, and productivity), and tools that support managerial decision making. Financial tools form a subset of general business tools. The classification of business tools by Bocij (et al, 1999) is too general, and a more specific classification pertaining to the finance industry is suggested by the author. The latter classification highlights special purpose tools that can be used only in a financial context. Such tools can be divided into three broad categories (cf. Figure 2.1):

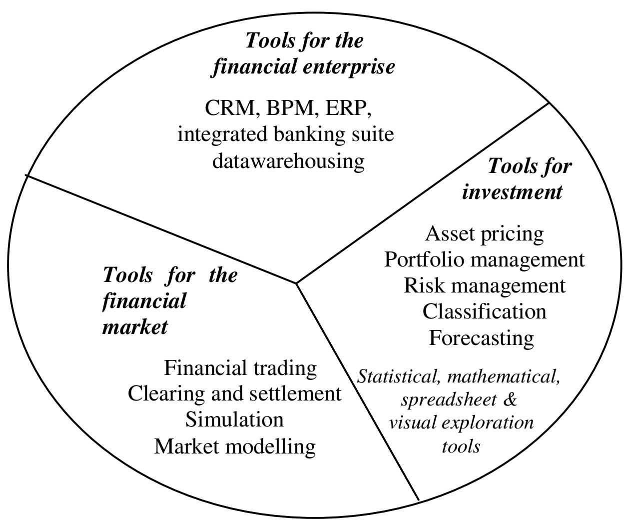


**Figure 2.1** classification of tools used in the financial industry

Financial enterprises use different tools to conduct their daily operations and maintain a competitive position in the global market. Integrated suites of tools have been developed by some service providers to offer a unified functionality. There is no clear academic description of the features of tools supporting operations in the financial enterprise. The author referred to the description of commercial computer packages[1] for financial operation as well as non

[1] Extended enterprise ebanking engine (http://www.systemaccess.com)
Integrated back office for corporate & universal banking (http://www.midas-kapiti.com/)

academic journals[2] to provide the description of tools in this category. Appendix 2.2 provides a detailed overview of the features of tools for the financial enterprise outlined below.

- *Enterprise Resource Planning tools(ERP):* handle the internal operations of a financial enterprise firm and automate its processes.
- *Customer Relationship Management[3] tools:* capture all the relevant information about customers and their needs via multiple channels (e.g. telephone, fax, internet), store this information in databases, and analyse it using data-mining and business intelligence tools.
- *Electronic Document Management (EDM) tools:* help in storing, retrieving and managing the workflow of documents across the enterprise, and in undertaking collaborative work.
- *Multi-channel integration tools:* are used to maintain consistency across multiple delivery channels.
- *Business Process Modelling tools:* support the re-engineering of the financial enterprise. Today organisations are facing continuous change, and the effect of this change on business efficiency is highly unpredictable and risky. Modelling and simulation tools have been developed to take the risk out of change.
- *Data warehousing tools:* support the management of the data-warehouse[4]. This involves the process of integrating enterprise wide corporate data into a single repository supporting a variety of decision analysis functions as well as strategic operational functions.
- *e-banking integrated suite of tools:* support online trading and banking services including orders execution, viewing accounts, portfolio monitoring, applications filling, and posting inquiries.

The above overview of tools highlights diverse functionality, widespread application, various needs, and novel uses of the computer. An integrated chain of tools with a common

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Wireless financial trading (http://www.jiway.com/)
e-processing for financial services (http://www.sungard.com/)
global financial crossing (http://www.ixnet.com/homepage.html)
Thomson Financial – providers of data, analysis and financial tools (http://www.thomsonfinancial.com/)
IT system for a screen-based order-driven exchange (http://www.isma.org/coredeal1.html)

[2] Banking Technology magazine, Straight Through Processing magazine (Financial Publishing International), Exchange (The magazine of London Stock Exchange), Computers and Finance magazine.

[3] Customer relationship management is referred to as the ability to capture a customer and to satisfy all their needs and requirements with minimum cost and high efficiency

[4] A data warehouse contains a collection of data from various operational systems and sources. It can be used as an integrated information base for making decisions and solving problems.

technology base is necessary to enable the process of turning information into knowledge shared across the financial enterprise.

Appendix 2.1 depicts the organizational structure of different financial intermediaries including banks, stock exchanges, and clearing and settlement institutions. Different departments in the financial enterprise rely on different tools, but a common knowledge base relying on the integration of different tools and a unified data-warehouse is necessary to support top management decisions and inter-department internal communication.

#### 2.1.1.2 The Integration of Human and Computing Activities

With the increased reliance on the power of the computer to conduct the daily operation in the financial enterprise and to support essential change, the integration of human and computing activities becomes more and more important. Software tools and devices are operated by humans and the failure to integrate the human factor in the software system development process reduces the usability and reliability of the tools to perform the intended task and to deal with singular situations as and when they arise. The integration of human and computing activities is necessary at many levels: interface, system analysis, system design and product design. A critical success factor for tools used in the financial enterprise is taking into account the human factor in every stage of the analysis, design, development, testing, and use of the tool. The need for the integration of human and computing activities is highlighted with reference to the above overviewed tools:

- Customer relationship management is a human centric activity and the use of technology to support it requires a high level of integration of the human and device[5] activities. The challenge of computer-based technology is to support the saying of Andrew Fisher "The customer is always right" by finding out more about customers, their buying habits, tastes and spending levels. This is also supported by the view of Mattu (2001) on understanding customer relationship management.
- Business process modelling is not only about processes but also about the human role in participating in the business process model. Technology support for business process modelling should account for the role, behaviour, and interaction of different human participants in the process. This is supported by Davenport's (1996) view published in his article "Why Re-engineering Failed: The Fad that Forgot People" on the cause of the failure of re-engineering projects in the United States. Vidgen et al. (1994) points out that

[5] The term device encompasses the computer and its multimedia support.

BPR has more of an organizational focus than a technical one and that the central tenet of BPR is to devise new ways of organizing tasks, organizing people and making use of IT so that the resulting processes better support the goals of the organization.

- The data warehouse is the information asset of the financial enterprise. Management of the data warehouse requires the integration of the human expertise and the domain knowledge in meta-modelling of the data and its storage and retrieval from different repositories. Tools for the data warehouse should enable human input and feedback at every stage of the information loading. This can transform the data warehouse into a reliable knowledge base for strategic decision support. This is supported by the professional view of Peter Block' s *Flawless Consulting* on warehouse projects[6] *"Warehouse projects will fail if the builders get specs from the users, go off for 6 months, and then come back with the 'finished' project. Warehouses are iterative! (I think the word iterative means there are lots of mistakes in the projects.) Builders and users working with each other will not reduce the number of iterations, but it will reduce the size of them."*
- Electronic document management is not limited to the transfer of documents throughout corporate networks. Documents contain valuable information for the enterprise. Failing to integrate the human interpretation of the document content with its permissible workflow reduces the reliability of electronic document management tools. Information security, and human understanding of the document content should be freely introduced at all stages of the electronic document management process to approve, or re-direct, the workflow of documents as and when necessary. The importance of the integration of the human and computing activities related to electronic document management is supported by Waldron's (2000) view on the complexity of the electronic record management: *"The value of electronic records management ERM has suddenly grown – as organisations increasingly hold vital transactions and documents in electronic form, and companies move to electronic processes …. The management of electronic records is complex as it requires a large range of functionality to be implemented well. ERM software may consist of a specialist package, a number of integrated packages, custom-designed software or some combination of these; in all cases, there will be a need for complementary manual procedures and management policies"*

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[6] In "Actions for datawarehouse success" at http://www.dwinfocenter.org/success.html

- Electronic banking is becoming the new popular banking model. Face to face interaction of client / bank personnel is replaced by fill-in forms that capture to some extent the client needs and requirements. Multimedia support attempts to replace / complement the human intervention in the electronic banking activity. A proper technology integration and multimedia support are not enough for the success of electronic banking activity. Human judgement and pro-active intervention to deal with singular situations should be enabled at every stage of the electronic banking activity. In discussing the right infrastructure for e-business, Christopherson (2000) points out the importance of gaining a thorough understanding of the business and how well all the core functions interact internally with employees and externally with supplier and customers. He added that true e-business performance can only be achieved if all elements of the infrastructure are integrated, including key business processes and end-user functions.

#### 2.1.1.3 Coherent integration of computer mediated group social activities

Efficient internal (within the financial enterprises) and external (across different financial enterprise) communication is a critical success factor in a competitive and global environment. Generic network tools, telephone, and fax communication tend to be replaced by more sophisticated environments for virtual collaboration. Essinger (1993) identified two roles for computer-based technology in solving the problem of maximizing the effectiveness of communication in retail financial institutions by enhancing the effectiveness of communication facilities used by customers and communication facilities relating to administration. Communication facilities providing a collaborative mode of interaction would better support computer mediated group activities at the administrative and operational level.

Taking account of the situatedness of the collaboration activity within a social network is an important factor. Human interaction with programmable components and devices is shaped by the context of the collaboration network [Son99].

Assessing the collaboration needs and requirements within and across financial enterprises is a challenging task. The primitive description of the organizational structure of different types of financial intermediaries inspires different modes and requirements for collaboration in each and every institution depending on its targeted goals and objectives. The workflow for clearing and settlement of the financial trade transaction (cf. Appendix 2.1) is a direct example highlighting the need for virtual collaboration across and within the financial enterprise. The organizational structure of a bank and a stock exchange (cf. Appendix 2.1) reveals different needs for collaboration. The regulatory body in the stock exchange should have a high control over the capital raising and trading services activity. Retail banking services, corporate banking, local and global investment benefit from suitable modes and means for collaboration to assess the bank performance and inform top management of banking business progress. Research on the organizational structure of financial enterprises feeds the requirement engineering of building virtual environments for collaboration across and within the financial enterprise. This is an ambitious project that demands a highly interdisciplinary research.

### 2.1.2 Application of Computer-based Technology in financial markets

> *"The financial markets are simply a huge clearing house where the different financial needs of individuals, companies and governments can be brought together and matched through appropriate pricing mechanisms. They might be actual places or they might be networks of computer screens and telephones. Either way, they address two fundamental needs: what is variously known as saving, lending or investing. The players in the financial markets and in the wider economy can be classified into four broad groups: investors (who have money to spare on assets), companies (which want to borrow money to expand their business), financial institutions (which act as intermediaries between borrowers and lenders), and governments (which act as both borrowers and lenders and play an important role in regulating the market)."*
> [Vai96]

In the financial market, the uses and applications of computer-based technology are diverse and rising with the shift from an old to a new trading model. Tools for the financial market are classified as educational, operational, and research analysis tools (cf. Appendix 2.2). Relevant academic financial research that investigates the new trading model relates to studies in financial market microstructure[7].

[7] Market microstructure is the academic name for the branch of financial economics that investigates trading and the organization of securities markets. This important field of study has grown substantially since the Stock Market Crash of 1987 [Har98]. Market microstructure analyses security trading and pricing at the institutional/market level. It focuses on modelling the influence of transactions costs on security pricing. By taking a broader view of the financial market structure, this field of study attempts to improve on the 'black box' modelling of equilibrium asset pricing, by accounting for strategic behaviour among trading parties [Abh00-1]. Financial market microstructure studies market structures and market efficiency, transparency, liquidity, volatility, competition, fragmentation, and economic

The key issue for the application of computer-based technology in the financial market is *supporting the shift towards a new trading model*. This involves the development of *computer-based models* reflecting stock exchange integration, enhanced operation (straight through processing, cross border trading) / trading cost reduction, re-engineering, advanced financial market analysis, domain knowledge construction and decision making needs and requirements. This would ultimately serve the purpose of building virtual environments for financial trading adapting to the new trading model.

#### 2.1.2.1 Modelling stock exchange integration

Today, traditional regulated stock exchanges are no longer the only players in the financial market. Traditional exchanges such as NYSE, LSE, and Tokyo stock exchanges, etc., that have a physical location are facing great competition from their electronic counterparts such as NASDAQ, EASDAQ, the quasi exchanges (known as Electronic Communication Networks – ECN), and the alternative trading systems. Alternative Trading Systems (ATS) are growing faster in the US market than in the European markets. ATSs in the US captured 3.1%, 8.1%, and 13% of the total US trading volume in 1990, 1995, and 1997 respectively, and are being used by more than 82% of US fund managers [Hay00].

In face of the competition, traditional exchanges are looking for integration and merger to survive in the global marketplace. Moreover, the old trading model adopted by traditional exchanges is no longer adequate and new trading models are being introduced, revolutionising old execution, clearing and settlement processes. The future of exchanges is unpredictable: trading is becoming easy but the great concern is also to make the settlement and clearing easy as well. The co-operation of exchanges is important but no one can foresee the future trend in co-operation between exchanges.

The technical challenges for integration can be framed in having a unified data structure, communication protocol, type of processing (real time vs. batch), and trading model. However, different trading platforms are difficult to integrate due to system design rigidity and lack of coherent structure. Different data communication standards have been introduced

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welfare. It investigates orders and order properties, attempts to answer the question "why do people trade?", analyses the type of trading (informed/uninformed), and the behaviour of market participants (investors, brokers, dealers). Appendix 2.3 introduces some basic concepts and definitions in the financial market microstructure area.

(such as FIX[8], XML[9] - extended markup language, OFX[10] - open financial exchange) to facilitate integration purposes, but this integration cannot succeed without a supporting regulatory framework.

Stock exchanges integration entails social, legislative, and technical considerations. It is difficult to study the requirements of social, technical, and legislative integration of stock exchanges separately. Successful integration relies on a consolidated integration plan where technology plays an important role in the requirement engineering of social and legislative integration requirements, and enabling technical integration. The characteristics of financial markets microstructure (cf. Appendix 2.3) reveal the challenges facing the integration of stock exchanges with heterogeneous microstructure (trading sessions, execution systems, and information systems). The agenda for stock exchange integration relies on interdisciplinary research in law, finance, and IT. This research would support an open financial market model informing, amongst other things, the requirements engineering for technology integration of different stock exchanges.

#### 2.1.2.2 Modelling for enhanced operation / lower transaction cost

Online investors are looking for the best trading prices, lowest trading cost, maximum market liquidity, anonymous trading, and easier cross border trading. Haynes (2000) subdivided trading cost into a visible and hidden part (cf. Appendix 2.3). The visible part includes taxes, commission, and spread, while the hidden part of the trading cost includes market impact and delay. In cross-border trading, settlement cost represents a proportionately bigger component

[8] The Financial Information eXchange (FIX) protocol is a messaging standard developed specifically for the real-time electronic exchange of securities transactions. FIX is a public-domain specification owned and maintained by FIX Protocol, Ltd. The mission of the organization is to improve the global trading process by defining, managing, and promoting an open protocol for real-time, electronic communication between industry participants, while complementing industry standards. (For more information visit http://www.siliconsummit.com/fixcenter.html)

[9] The Extensible Markup Language (XML) introduced by the World Wide Web Consortium in 1996 provides a standard approach for describing, capturing, processing, and publishing information over the internet [McG98]. Whereas HTML allows the structural markup of web documents, distinguishing the elements of a page with tags and declaring the physical relationships among the various document elements (new paragraph, head, body), thus allowing human to read it and use it. XML provides a semantic markup (identifying what each particular element means) which is a machine readable structured content.

[10] Open Financial Exchange is a unified specification for the electronic exchange of financial data between financial institutions, business and consumers via the Internet. Created by CheckFree, Intuit and Microsoft in early 1997, Open Financial Exchange supports a wide range of financial activities including consumer and small business banking; consumer and small business bill payment; bill presentment and investments, including stocks, bonds and mutual funds.

of the total trading cost. Efforts are conducted at the international markets level to reduce trading cost by reducing the trading process time and stages. The investment trading process has different stages: order execution, clearance and settlement that can be accomplished in different time intervals up to a maximum of 5 time intervals [Mil99]. This is illustrated in Appendix 2.3.

Straight through processing is the ultimate objective of the new trading model[11]. The seven stages for the execution of an investment trade (trade execution, notice of execution, trade allocation, trade comparison, trade confirmation and reporting, bank notification, clearance and settlement), identified by Milne (1999), are usually executed during five different time intervals. Straight through processing allows the execution of all the stages in one time interval, thus reducing the risk and cost of the trade settlement and improving the market liquidity. Reichardt (1999) argues that the main challenges facing the application of straight through processing is the need for large investment in real-time technology, a deep understanding of the related business issues, industry co-operation on common issues, the acceptance of standards, and the integration of front-office and back-office technologies.

A major challenge facing global electronic trading is providing straight through processing (STP) of transactions, re-designing workflow and processes, and determining the data protocols and connectivity.

Facilitating cross border trading is another challenge facing stock exchanges seeking survival in the global market. Cross border trading requires a geographical spread of the technological, social and legislative infrastructure of a stock exchange. Extending the technology infrastructure of financial trading requires an appropriate re-engineering of the trading system to accommodate different legislative and social framework. This will be reflected in the interface, internal design, and networking of electronic trading systems.

#### 2.1.2.3 Modelling the new financial trading environment

Computerisation is about to overtake markets that traditionally depended on physical presence to bring buyers and sellers together in one place. A new trading model is emerging where individual investors have access to a wealth of market data, research can be easily conducted, plenty of trading choices are offered, online brokers have a retail focus, and a new global trading community is formed [Per99]. The new financial trading model demands new

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[11] Reichardt (1999) defined Straight Through Processing (STP) as "fully automated, hands-free processing of security transactions from the fund manager's decision right through to settlement, reconciliation and reporting". It is also defined as "the vertical integration of services from trading to settlement reconciliation, or processing without manual intervention".

legislation for regulating exchanges, quasi-exchanges, and global financial markets. This new legislation should be concerned with taxation, IT systems, operational risk, new standards (transparency, record keeping, listing), legal identity to quasi-exchanges, reduction of national market monopolies, and delivery of financial services over the internet.

Attempts at modelling the new trading environment are approached in: i. academic financial research; ii. interdisciplinary research in computer-based technology and finance; and iii. research on novel software engineering practices for the financial markets.

i. Modelling the new financial trading environment, in academic financial research, involves models for testing market efficiency (cf. Appendix 2.3) and analysing the microstructure of financial markets. Typical research in this area includes, among others, the work undertaken by Oedan et al (2000) - analysing the behaviour and profitability of online investors; Rime et al (2000) - analysing the impact of the introduction of electronic brokers on the structure of foreign exchange market (FX); Jennings et al (2000) - comparing floor trading in NYSE to over-the-counter trading in NASDAQ with reference to best execution prices[12]; Coval et al (2000) - analysing the information content of the ambient noise level in the Chicago Board of Trade' s 30-year Treasury Bond futures trading pit; Rolls (1984) - inferring the effective bid-ask spread from security returns (the first-order serial covariance of rates of return); Harris (1988), Hsia, Fuller, and Kao (1994) - extending Roll's model to solve the problem of imaginary numbers in the estimation of the effective bid-ask spread; Eckbo and Smith (1998) - monitoring the movement of insider trading in technically advanced financial markets; Harris (1998) – presenting a detailed overview of how existing markets are organised and regulated, and attempting to answer the question of what are the markets supposed to do and for whom; and Taylor et al (1998) - assessing the relationship between a trading system operated by a stock exchange (SETS operated by London Stock Exchange) and the trading behaviour of heterogeneous investors who use the exchange. In the latter model, Taylor used the cost-of-carry model of futures prices to estimate the transaction costs and trade speeds faced by arbitrageurs who take advantage of mis-pricing of FTSE100 futures contracts relative to the spot prices of the stocks that make up the FTSE100 stock index.

ii. Inter-disciplinary research (computer and finance) can help in the analysis of the effect of structural change in financial markets. The study undertaken by Konana, Menon, and

[12] Best execution is assessed in terms of trade prices and contemporaneous quoted prices, speed of execution, and liquidity enhancement.

Balasubramanian (2000) evaluates the impact of online investment on the efficiency[13] of financial markets and the trading system in the short and long term horizon. Two models describing the investor choice process and the revenue flow and incurred cost in online trading are presented. The models take the form of static diagram illustrating the workflow of a financial transaction.

iii. The shift from an old to a new trading model motivates the re-engineering or the development of new virtual environment for financial trading and the adoption of new software engineering practices. So far, there is no proper description of the new trading model that can inform the re-engineering / development of new trading systems. Knowledge of the new trading model is gradually constructed and continuously evolving over time to accommodate new patterns and modes of trading and behaviour of different market participants. This poses a challenge for computational models of software system development that begins with an engineering requirement stage and terminates with an end product delivery at a final stage. The weakly structured knowledge surrounding the new trading model motivates the re-thinking of the software engineering and software system development process to take into account a growing boundary for the system being developed and continuous knowledge construction informing improvement of the final end-product delivery. Providing appropriate interfaces for virtual environments for financial trading is another major challenge. In the context of financial trading, the behaviour of different trading parties (investors, brokers and dealers), trading signals, economic and financial indicators, and trading systems, constitutes a complex environment which is difficult to capture in a mathematical model, a computer simulation, or a textual description. This motivates the integration of different technologies to support the development of virtual environments for financial trading meeting the requirements of the new trading model.

### 2.1.3 Application of Computer-based Technology in Investment

*'Investment can be divided, both in theory and practice, into two parts security analysis and portfolio management. Security analysis attempts to determine whether an individual security is correctly valued in the marketplace. Portfolio management is the process of combining securities into a portfolio tailored to the*

[13] In [KMB00], the processes determining market efficiency include: order flow, price discovery, and order execution. In that context, two types of market efficiency are identified: the efficiency perceived by investors, and the real efficiency of the transactions and the patterns of information flows beyond the interface.

*investor's preferences and needs, monitoring that portfolio, and evaluating its performance. The three main themes of investments are: the risk-return tradeoff and the principle of modern portfolio theory and efficient diversification, active versus passive portfolio management, and equilibrium pricing relationships" [BKM96].*

Associated with investment is the financial engineering process that consists of developing new financial instruments that meet different risk/return profiles. The elaboration on investment themes and the different types of financial instruments is given in Appendix 2.4.

Tools for investment including financial analysis and modelling tools (General purpose OLAP (Online Analytical Processing) , Data mining, Spreadsheet , Visual exploration tools, Risk assessment tools, Market prediction tools, Portfolio management tools, Numerical Libraries, Statistical packages), educational tools and financial engineering tools are overviewed in Appendix 2.2.

The key issues of the application of computer-based technology in investment are supporting the financial engineering activity as a group social activity whilst providing increased flexibility for the financial modelling activity, and providing greater support for the finance research development cycle that informs investment and financial market analysis.

#### 2.1.3.1 Providing greater support and flexibility for the distributed financial modelling activity

Finance is borrowing new principles from engineering, and the term 'financial engineering" refers to the development of new financial instruments meeting clients' requirements to hedge against risk and maintain a profitable position. Like engineers, financial experts build prototypes of a financial model and share it across a network of financial experts to analyse and discuss its prospect in meeting clients' needs and requirements.

Developing new financial instruments satisfying rising needs and requirements in a global market does not involve only financial analysis relying on the implementation of mathematical models. The financial engineering process is a complex collaborative activity that results in the delivery of a final product tailored to customer needs. Providing a computer-based support for the financial engineering activity is highly dependent on effective support for interpersonal interaction in the course of engineering a financial product.

#### 2.1.3.2 Providing greater support for the financial research development activity

Financial research is broadly described in terms of data collection, methodologies selection, methodologies implementation, result analysis, and conclusions. Computer-based support of the financial research development cycle varies at various stages of this activity. It may take the form of data storage and retrieval in the collection stage; spreadsheet or high level language programming support in the implementation and result analysis stage. Various tools exist to support particular stages in the research development cycle. A closer view of the financial research development activity can potentially provide us with means for an adequate software system development support.

## 2.2 Meeting The Needs of the Wider Agenda of Computing

Section 2.1 overviewed the key issues for the application of computer-based technology in the finance domain at the enterprise, market, and investment levels. They can be summarised as follows: integration that takes different forms; novel computer-based modelling to accommodate change and rising needs; and novel software system development practices. The above identified issues suggest a wider agenda for the computational activity that draws on existing computational practices and solicits a broader foundation of computing capable of addressing technical and strategic demands of the application of computer-based technology in finance.

The *technical demands* refers to the characteristics that we expect of computer-based technology and the concerns that have to do with how computer software is generated. These demands include: i) dealing with experiential issues; ii) enabling closer integration of the manual and automatic interactions; iii) promoting flexible software system development; and iv) supporting new computer-related technologies.

The *strategic demands* are the aspirations that we have for real-world activities using computer-based technology. They entail: i) providing qualitative decision support; ii) facilitating open-ended flexible modelling; iii) integrating the software system development activity with activities in the real world; iv) establishing different paradigms for human-computer co-operation that are better positioned to support business process modelling; and v) integrating diverse kinds of agency. Meeting these strategic demands is referred to throughout this thesis as 'the wider agenda for computing".

The wider agenda for computing suggests a more intimate (semantic) relationship between the computing activity and activities in the real world (e.g. business and finance related) than that offered by conventional computer science. The latter assumes an application interface that separates the computer-related activities (design, analysis, and programming) from the real world activities and their corresponding domain analysis. This is facilitated by the abstraction and circumscription of the real world applications (cf. Figure 2.2). Figure 2.3 suggests an evolving semantic relationship between the computing activity and activities in the real world. Such a relationship can potentially provide suitable computer-based support for the real world activities by integrating computer-related analysis and modelling with real world domain analysis and modelling.

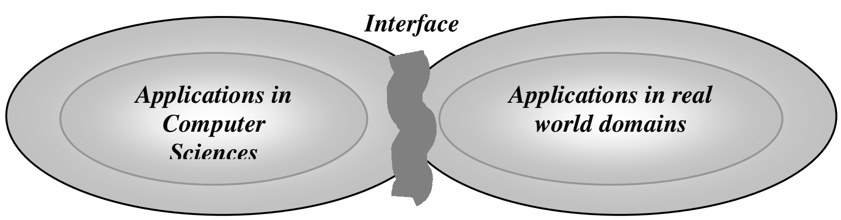


**Figure 2.2** The interface between applications in computer sciences and applications in real world domains

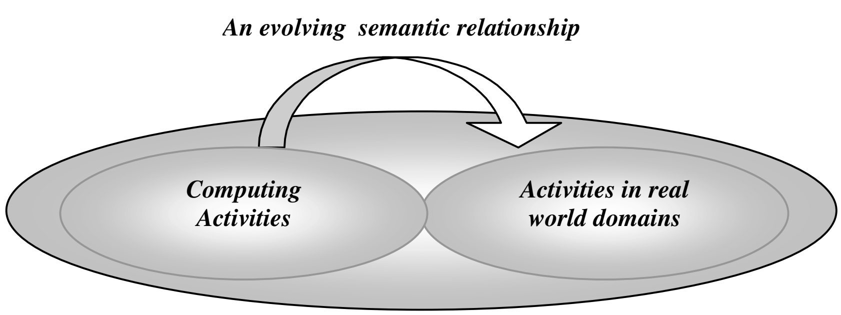


**Figure 2.3** The wider agenda for computing: a more intimate relationship between computing and activities in real world domains

Current tools and technologies face major challenges in meeting the technical and strategic demands of the wider agenda for computing. These challenges are overviewed in the following sub-sections.

### 2.2.1 Tools limitation

The software industry has witnessed a noticeable progress in the development of various tools meeting different requirements and needs. However, many obstacles are posed in exploiting the use of these tools in meeting the need and requirements of a growing and changing financial industry. These include:

- *The adoption of rigid software system development approaches*: A major reason why the benefits of software implementation have been so slow in coming is that system complexity is not adequately managed. Financial enterprises and markets require more complex trading and operational systems with the shift toward integration and enhanced operation (STP, cross border trading, low transaction costs). This makes the software system development activity more complex. Introducing changes to complex applications is very difficult or even impossible in the absence of an interactive flexible approach to software system development that takes account of a growing system boundary and the social aspect of an application domain.
- *The difficulty of moving from the problem domain (real world application) to the solution domain (world of programs and systems):* There is currently a wide gap between research and development, and target goals and current achievement. Bridging these gaps is not only a technical issue but also entails management and communication issues. Heeks (1998) argues that most IT systems failures are due to a conception-reality gap between the rational conceptions of information system initiatives and the behavioural/political realities of organisations. This is also acknowledged by ongoing research that attempts to comprehend the relationship between software engineering and business process modelling [FRKBPJ00].
- *The rising cost and complexity:* Current pressures are obliging the software industry to build faster applications with more control and higher quality at lower cost and effort. However, as complexity increases, cost and development time escalate.
- *The limitation of the underlying technology:* many software products launched in the market are not well-suited for describing interaction in a multi-user environment with many applications. Interaction in the financial market is subtle and complex, and building

trading systems that accommodate this high level of complexity requires a broad foundation of computing borrowing from disparate disciplines.

- *The limited functionality:* most of the tools are built with preconceived functionality in mind. This reduces the adaptability of the tools to rising needs and requirements. Addressing this issue involves placing greater emphasis on the modelling rather than the programming activity. The choice of modelling paradigm also has a great influence on the functionality of the end product. Making an appropriate translation of the model into an application program is also a challenging task. The new trading model is weakly structured. This motivates an open-ended modelling paradigm that continuously informs end product development. This is very ambitious given the difficulty of establishing a semantic relationship between the end product and the continuously evolving model.
- *The limitation of the underlying theory:* most of the financial analysis tools (including financial instruments pricing, risk assessment, neural networks, and investment strategies, etc..) rely on an underlying mathematical model. Investment themes (cf. Appendix 2.4) reveal a striking conflict in adopted theories. This is expressed in the conflict in equilibrium pricing relationships [Rol77] (the use of capital asset pricing model [Sha64, Lin65] vs arbitrage pricing theory [Ros76]) and trading strategies [Gol88] (fundamentalist vs chartist). Moreover, the efficient market hypothesis [Fam70, Fam91] (cf. Appendix 2.3) raises questions concerning the use of tools that analyse past historical data and inform future action in efficient markets where prices follow a random walk [Mal99]. These conflicts motivate the consideration of an experience-based approach to building tools for financial analysis and decision support. Financial modelling tools that implement a formally established financial theory might fail to deliver the intended decision support. This is because financial theories are based on a set of assumptions and take into consideration a limited number of economic and financial factors. This undermines the reliability of financial modelling in supporting proper decision-making, especially when the assumptions do not hold and more economic and financial factors need to be taken into consideration.

### 2.2.2 Technologies limitation

Underlying technologies used in the development of tools for the financial industry are numerous. They include Object Oriented, Artificial Intelligence, Database, VR, and web technologies. Many limitations are acknowledged in these technologies relating both to foundational principles and to issues for applications and implementations.

#### 2.2.2.1 Object Oriented Technology

*Motivations*

The object oriented approach is adopted in the development of many tools and systems in the financial industry[14]. This is motivated by three considerations: the possibility of developing applications of increasing complexity; the need to reduce the cost of development and maintenance; and the evolution of classical business applications from storing / retrieving / coding information to representing complex objects and more elaborate processing encompassing business control, rule-based reasoning and decision making [BGV97].

*Historical background*

Object oriented technology relies on the concept of object introduced in [DN66], the theory of abstract data types formalized in [LZ75], the concept of message passing and inheritance introduced in [HBS73], and the linking of objects by the "is-a" relation introduced in [Win84].

*Applications*

The widespread use of object technology is attributed to two reasons: objects seem to be a good abstraction of real world entities and can be used in modelling complex systems; and objects are modular and can be re-used in complex applications.

In Object Oriented Modelling, the object concept is associated with encapsulated units of data and operations. Documents, transactions, products, individuals in our daily business life are modelled as objects such as invoices, orders, and customers. In relating to each other, to system users and to the outside world these objects are self-managing. A business object is a representation of a thing active in the business domain, including at least its business name and definition, attributes, behaviour, relationships, rules, policies and constraints. A business object may represent, for example, a person, place, event, business process or concept.

*Challenges*

Major challenges face object oriented technology and its application in different areas. These include:

- *Design and development problems:* Despite its popularity, object oriented technology cannot solve all design and development problems. Bouzeghoub (et al, 1997) argues that there is still considerable confusion and controversy over key concepts of OO technology, such as encapsulation[15], inheritance[16], and polymorphism[17].

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[14] See technology used in Misys International Banking Systems Ltd (http://www.misys-ibs.com/).

[15] Encapsulation of the data is the application of the principle of abstraction into objects and operations that manipulate the object (classes and methods). Objects are accessible only by means of their visible operations, the implementation of objects is hidden from the program that manipulate them).

[16] Inheritance is the essential distinguishing feature of object languages. It can be simple or multiple and can support polymorphism of operations. It is basically the mechanism of transmitting the properties of a class to a subclass.

- *The difficulty of object identification:* Another challenge facing object oriented technology is the difficulty of identifying objects and their behaviour in a system at an early stage. This motivates the support of object oriented technology with other technologies capable of modelling a weakly structured domain and identifying candidate objects and their reliable repetitive patterns of behaviour. Such a supporting technology would precede OO analysis and rely on an experience based approach to understand a problem domain.
- *The OO analysis and design gap:* Reconciling object oriented analysis and design is a major challenge acknowledged in [Kai99].
- *The difficulty of modelling weakly structured domains:* The object oriented approach does not deal with partial knowledge of the real world. Object attributes are predefined at an early stage in program design. Problems arise with the emergence of new knowledge which reshape the real life aspect of these objects. Inheritance and encapsulation minimize the overhead of code re-engineering to integrate the change, however the amount of adjustment is still considerable. Exploiting object oriented software engineering methodologies for business process modelling is challenged by the weakly structured domain knowledge [FRKBCJ00].
- *The minimal added value in certain application domains:* Eber (1999) argues that object oriented technology does not deliver any added value to financial modelling as compared to a high level language such as C++ or Pascal. Object Oriented technology is just another way to write a program and it does not lead to much improvement in financial reasoning or financial model implementation.

#### 2.2.2.2 AI technology

*Motivations*

Broadly speaking, AI technology is concerned with creating computer programs that can perform actions comparable to human decision making [Shap92].

*Historical background*

The underlying assumptions of a large body of research in AI rely on Newell and Simon's (1976) physical symbol system[18] hypothesis [NS76] that "a physical symbol system has the necessary and sufficient means for general intelligent actions". The truth of this hypothesis is

[17] Polymorphism is the re-definition of inherited method to give it a different implementation (to code it differently).

[18] A physical symbol system consists of a set of entities, called symbols, which are physical patterns that can occur as components of another type of entity called an expression (or symbol structure) [NS76].

to be assessed by experimentation, and computers provide the perfect medium for this experimentation.

AI techniques are classified into two main classes: methods for representing and using knowledge and methods for conducting heuristic search. These aim at developing adaptive systems (systems that learn or adapt in response to outside events according to their previous ' experience' ). Artificial intelligence technologies include neural networks[19], genetic algorithms, fuzzy logic, etc. These techniques have been used for financial forecasting, credit rating, customer profiling and portfolio management [Dav91, FK95, Deb94].

*Applications*

AI practice has found widespread application in many areas including finance. The application of artificial intelligence in finance [TL96] investigates the use of knowledge-based systems (also called expert systems) to investment decision making. Decision support systems for investment integrate mathematical models, a data source, and a user interface. Knowledge based systems are decision support systems whose database include relevant theory, facts, and human knowledge and expertise. The finance and investment literature often fails to discuss even briefly computer implementations of the economic theories and principles involved in investment management. According to Trippi (et al, 1996), artificial intelligence in finance can be thought of as a bridge between finance and information science.

Artificial neural networks have fuelled the recent interest in non-linearities in financial data. Most econometric methods used in testing financial theories are designed to detect linear structure in financial data. For instance, the Capital Asset Pricing Model (CAPM) and the Arbitrage Pricing Theory (APT) are based on linear models of expected returns. However, many aspects of economic behaviour may not be linear. Experimental evidence and causal introspection suggest that the relationship between an investor’s attitude towards risk and his expected return is non-linear. Modelling the strategic interaction among market participants, the process by which information is incorporated into security prices, and the dynamics of economy-wide fluctuations is clearly beyond the scope of linear mathematical models. It seems that modelling of non-linear phenomena defines a natural frontier for financial econometrics [CLM97]. On this basis, Fama (1970) argues that traditional economic theory

[19] Neural networks are a collection of mathematical techniques that can be used for signal processing, forecasting, and clustering. Neural networks can be viewed as non-linear, multi-layered, parallel regression techniques. In simple terms, neural network modelling is like fitting a line, plane or hyperplane through a set of data points. A line, plane or hyperplane can be fitted through any set of data and define relationships that may exist between the input and outputs. There are two classes of neural networks: supervised neural nets (techniques for extracting input-output relationships from data); and unsupervised neural nets (techniques for classifying, organizing, and visualizing large data sets) [Dko98].

cannot be used to devise mechanised methods for predicting market movements at all. Economists of a new generation are creating new models and tools that can capture non-linearities in economic phenomena. Artificial neural networks are an alternative to non-parametric regression and have received recent attention in the engineering and business communities.

The importance of the use of artificial intelligence techniques in financial modelling is emphasised by Ridley (1993). In Ridley's view market trading relies on intuitive and complex reasoning on the part of the human trader. The trader interprets and deciphers many factors surrounding the market of interest. The factors can be wide ranging and can vary over time. This kind of changing structural relationship implies that the form of decision process required by market trading is not open to precise calculation and therefore not open to mechanisation [Fam70].

*Challenges* Despite its penetration in various application domains, artificial intelligence technology still faces many challenges:

- *Rigidity of the AI solution:* In facing the challenge of building real-world systems, AI faces a criticism of the rigidity of the solution it produces. Some researchers attribute this fact to the difficulty faced by AI to scale well beyond the relatively small domains to which they have been applied. Moreover, the performance of an AI system is extremely sensitive to the representational choices made by its designer and these are subtle in the face of the inevitable deviations from the norm found in the real world. As was first pointed out by Dreyfus (1979), the success of an AI system appears to be strongly correlated with the degree to which the problem domain can be treated as an abstract micro-world which is disconnected from the real world at large.
- *The difficulty of abstracting various aspects of the complex real world domain:* The fundamental AI approach of subdividing mental activities into independent tasks (ordinary, formal, and expert task), the hypothesis of the physical symbol system, the focus on structured knowledge management, the four-step problem solving mechanism, and the knowledge management techniques, are viewed by many as an oversimplification when solving complex inter-related problems requiring ordinary, formal, and expert tasks. In contrast, many modern approaches to problem solving emphasize the importance of thinking in embodied and embedded terms [Cla01].
- *Dealing with domain specific characteristics:* Despite the developing importance of the use of artificial intelligence in the financial community, the Efficient Market Hypothesis (EMH) still poses a significant challenge for a machine learning AI system. If the EMH

holds true then no solution exists to predict the market, and all AI systems are doomed to fail no matter how sophisticated they are. If capital markets are efficient, then changes in stock prices should be associated exclusively with new information. This implies that information, once available, triggers a rapid process of adjustment for prices to their correct level, where it once more reflects all available information. This in turn implies that the movement in prices is random and is based on future events. Unless an AI system can anticipate the outbreak of war, or political events, or financial news, it is condemned to failure within the EMH framework [Mal99].

The above limitations facing conventional approaches to AI motivate a new foundation for artificial intelligence that emphasizes an experience based approach to understand a domain and construct the corresponding computer-based artefact.

#### 2.2.2.3 Virtual Reality technology

*Motivations* Virtual Reality technologies [MT94, LBBRS97, Kru83] supply virtual environments that have key characteristics in common with our physical environment. Viewing and interacting with 3D objects offers greater realism than abstract mathematical and 2D representations of the real world. In that respect virtual reality can potentially serve two objectives: (a) reflecting realism through a closer correspondence with real experience, and (b) extending the power of computer-based technology to better reflect "abstract" experience (interactions concerned with interpretation and manipulation of symbols that have no obvious embodiment e.g. share prices, as contrasted to interaction with physical objects). The main motivation for using VR to achieve objective (a) is cost reduction (e.g. it is cheaper to navigate a virtual environment depicting a physical location such as a theatre, a road, or a market, than to be in the physical location itself), and more scope for flexible interaction (e.g. interacting with a virtual object depicting a car allows more scope for viewing it from different locations and angles). Objective (b) can be better targeted because the available metaphors embrace representations in 3D-space (c.f. visualization of the genome).

*Applications* The dominant emphasis in current uses of VR is on the exploration of a real physical object (e.g. car, cube, molecule, etc..) or a physical location (e.g. shop, theatre, house, forest, etc..). In the course of exploration the user is immersed in the VR scene, and can walkthrough or fly through the scene. The user's body and mind integrate with this scene. This frees the intuition, curiosity and intelligence of the user in exploring the state of the scene. In a real context, agents intervene to change the state of current objects/situations (e.g. heat acts as an agent in expanding metallic objects, a dealer acts as an agent in changing bid/ask quotes and so affects the flow of buyers and sellers).

The use of virtual reality technology in finance was pioneered by the NYSE who developed the first large-scale virtual reality environment for navigating the stock exchange trading floor and the Advanced Trading Floor Operations Center in a 3D virtual scene[20].

The 3-D Trading Floor consolidates the data streams of NYSE operational activity into one highly advanced, three-dimensional graphic visualization system, revolutionizing the way the NYSE monitors and responds to systems and stock-related events. The 3DTF is a completely interactive, virtual representation of the trading floor that enables the NYSE operations staff to pinpoint complex systems activities and stock-related activity with remarkable visual clarity.

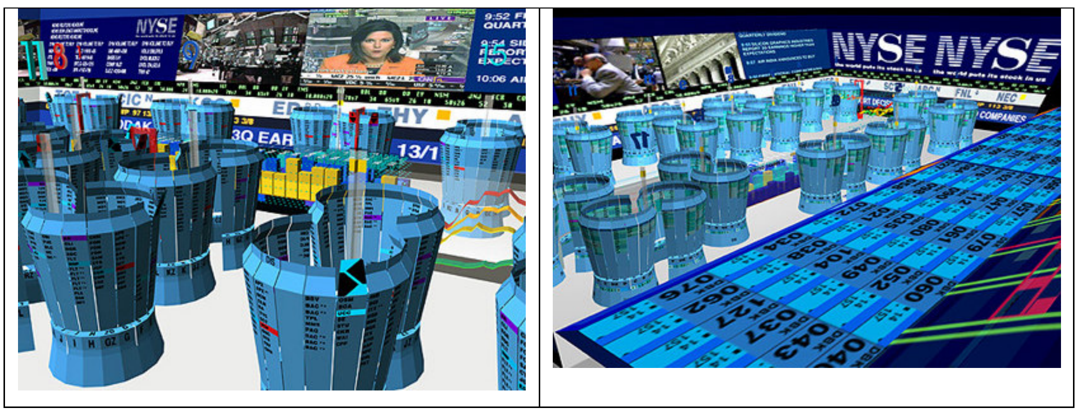


**Figure 2.4** The use of VR technology to depict the trading activity in NYSE

Such an application of VR technology in finance attempts to merge the mechanism of a trading process with the analysis of the results of the trading process in a synthesised 3D visual environment. This highlights the importance of the human visual system and its role in supporting knowledge construction about an environment.

*Challenges*

VR technology faces many challenges. These include technical challenges and limitations in respect of various application domains.

- *The lack of basic foundations for building VR environments:* There is no agreed software development practice for building virtual worlds and scenes. Current immersive virtual environments systems use a wide variety of programming methodologies and scene

[20] http://www.nyse.com/floor/floor.html

description languages (data flow models, visual languages, etc.), and although many support importation of VRML scenes, there is no agreement on how behaviour and interaction should be described [VEa98].

- *Limitations in respect of various application domains:* The challenges facing VR technology include integrating the social aspect of real world environments with their corresponding 3D visualization and animation in the 2D scene [MBG01]. Ontological issues bearing on the questions: "What is reality? What is virtual reality? What is the correspondence between the two?" are motivated in the application of VR technology to different application domains. The challenges facing the use of VR technology in modelling social application domains are due to limitations in the technology and in the principles underlying the technology. The technical limitation is due to the fact that information technology is not mature enough to capture all human sensations and simulate it by devices. Attempts at simulating human cognition and sensations with the aid of multimedia devices is an interdisciplinary research involving electronic devices, information processing systems, cognitive biology, human biology, sociology. VR technology lacks supporting principles for the integration of the social aspect in a virtual environment. Representing the human role in the virtual environment still poses major difficulty. Avatars are still primitive and limited to iconic representation of a human being.

#### 2.2.2.4 Database Technology

*Motivations*

Management of financial data (storage, retrieval and update) is very important in conducting financial analysis and forecasting. Data management paradigms evolved from files[21] to groupware[22] and databases[23] [Bla01]. Databases are concerned with storing and processing data on computers. Data analysis, data modelling, and data security are key issues addressed

[21] In the file processing approach data is accessed sequentially or randomly through a physical program interface. The file processing approach is not adequate for computer environments including many applications accessing many files.

[22] Groupware is software that manages unstructured information for collaborating users. Groupware organizes data into documents that consists of items. An example of a groupware data management application is Lotus Notes. Groupware has limited support for data management actions such as multi-user access, error recovery and flexible queries.

[23] A database is a permanent self descriptive store of data. It contains the data structure (schema) and the data. A database manager is the software managing access to the database. Different database paradigms exist: relational (where data is perceived as tables, and data is accessed by a relational database management system), multidimensional (tailored for analytical applications with complex relationships between data), object oriented (based on the concept of embodied objects, and relationships between objects established through pointers).

in database design and management. Database systems were motivated by the need to overcome the problems facing file processing applications, where files of structured data are processed by programs. Database systems first began to appear in the 1960s but, since then, have witnessed a major change in concepts and technology. A database management system (DBMS) consists of a collection of interrelated data and a set of programs to access that data [KS86]. Its primary goal is retrieving and storing information into a database. A database system provides the user with an abstract view of the data at three levels: physical level (describe how the data is stored); conceptual level (describe the data and relationship between data stored in the database), view level (describe part of the entire database). Different data models can be adopted at the conceptual and physical level: object-based logical model; record-based logical models; or physical data models.

*Applications*

Different financial markets rely on different financial data sets. Examples include the CRSP[24] Database for USA financial market data, the LSPD[25] (London Share Price Database) for UK market data, and the S&P' s Emerging Markets Data Base (EMDB[26]) for Emerging markets data.

*Challenges*

Many challenges are facing modern database technologies. These include:

- Providing appropriate visual interfaces
- Enabling selective access to data in world databases: this includes complex retrieval and search query.
- Providing end user programming: despite the advance in visual query languages, the aim of providing end user accessibility to large databases is difficult without resorting to high level 3rd generation languages. Users of World financial databases do not rely solely on the provided visual query to extract data for a single firm. High level programming in Fortran or C is usually resorted to in advanced manipulation of large financial databases.
- representing complex and various forms of data (e.g. relating to multimedia)
- Maintaining and representing complex relationship between data
- representing complex relationships between data of different types
- providing novel style of interaction with the database.

[24] www.crsp.uchicago.edu

[25] http://www.lbs.ac.uk/ifa/Services/London_Share_Price_Database/london_share_price_database.html

# 2.3 Conclusion

This chapter has identified key issues of the application of computer-based technology in finance at the institutional, market, and investment levels. This motivates the reconstruction of computing in a wider framework capable of addressing strategic and technical demands of computer-based support for the financial domain. The chapter considered the limitations of prevailing tools and technologies in meeting the wider agenda for computing in finance. This suggests a paradigm shift in software system development for the financial enterprise, the financial market, and investment.

Key issues for the application of computer-based technology in the financial enterprise motivate the need for a shift in perspective ***from***:

- methodical ***to*** amethodical software system development;
- formal approaches ***to*** situated experience based approach to software system development
- considering software system development as a technical activity ***to*** considering software system development as a social activity that needs computer-based support
- closed ***to*** open software system development

Key issues for the application of computer-based technology in the financial market motivate the need for a shift in perspective ***from***:

- programming an end product ***to*** modelling complex, weakly-structured knowledge of a domain
- abstract mathematical modelling ***to*** experience based modelling of the financial market
- rigid boundaries solution ***to*** growing boundaries solution
- full automation ***to*** human engagement in semi-automated activity

Key issues for the application of computer-based technology in investment motivate the need for a shift in perspective ***from***:

- a rigid financial research development cycle ***to*** a situated account of the financial development cycle
- closed ***to*** open functionality in financial modelling
- from supporting the financial engineering activity as a personal activity ***to*** supporting financial engineering as a group social activity.

[26] http://www.spglobal.com/indexmainemdb2000.html

Key issues for the applications of computer-based technology in the financial enterprise, financial market, and investment reveal a wider agenda for computing in finance that draws on:

- basic principles and foundations motivating a paradigm shift in software system development and novel computer uses and evolution
- integrated features in disparate technologies
- holistic approaches to tackle domain specific needs

The limitations of current tools and technologies to address the implications of the wider agenda of computing in finance on software system development practices and computer uses motivated the investigation of a suitable framework for deploying current prevalent technologies. EM technology aspires to develop the requirement engineering and to establish principles for such a framework that can potentially address the wider agenda for computing in finance. The application and prospects of this novel technology in the finance domain is the theme tackled in the next chapters. Case studies taken from the finance domain and addressing the key issues for the application of computer-based technology at the three finance levels are considered.