Chapter 9

Conclusion

9.0 Overview

This chapter summarizes the research presented in the thesis, highlights its limitations, and proposes further work to support the penetration of EM technology in the finance domain.

9.1 Research Summary

The research presented in this thesis was initially motivated by the author's interest in exploring computer-based support for finance. The author was attracted by the potential of EM technology to deliver a framework supporting primitive observation and experimentation in the financial domain. This is essential in construing phenomena that are difficult to capture in abstract mathematical models or to understand by applying econometric and logicist AI techniques on historical data sets.

The survey conducted on the finance domain and the application of computer-based technology in this domain reveals special characteristics and a diversity of tools and technologies. The finance, the computer and the communication industry are witnessing continuous change. It is difficult to identify exactly the drivers of change and it is clear that the pace of change will continue in the future.

"The only thing that won't change is the fact that everything will continue to change".

Timothy W. Ryan [Rya97].

The future will see further integration of computer tools, convergence of technologies (computer, communication, TV), new financial instruments, increasing financial market integration, new structures and new roles for participants in the financial market.

To suppose that all change can be handled by delivering a recipe is to fail to do justice to the true meaning of the concept of change. Experiencing change and describing this experience, in more human terms, though it may not lead to an efficient or an exact solution, can assist in coping with change without imposing a structure upon it.

Managing and coping with change is not straightforward. We need to understand this change, its implication, and its future direction. Describing change in a formal framework simplifies the reality behind change and hides its complexity. We need a framework that addresses the complexity of change without circumscribing or making erroneous assumptions about the pattern of this change. Be it broad human thinking or a broad computational framework or a combination of both, embracing the pace of change remains a big challenge for the human and the machine.

The thesis aims at addressing the need of a wider agenda for computing in the finance domain. It explores a computational framework, different in character from formal highly structured ones, and that can potentially cope with change with high flexibility and adaptability. This computational framework emphasizes situated actions, the human role

(including its weaknesses), and human machine collaboration whilst looking deeply at the requirements and implications of change.

The thesis has identified key issues for the application of computer-based technology in finance. These issues motivate a wider agenda for computing in finance. A paradigm shift at the computational level is needed to meet this agenda. EM technology has application and future prospects in the finance domain and can potentially meet this agenda's requirements.

The thesis has considered four case studies for the application of EM technology in Finance. The main findings of the research may be summarised as follows:

Identifying key issues for computer-based technology in finance

Key issues for the application of computer-based technology in finance are centred around software integration and virtual collaboration in the financial enterprise, the shift from the old to the new trading model in the financial market, computer mediated interpersonal interaction in financial engineering, and software system development for the financial research development cycle.

Framing the wider agenda for computing in finance

The wider agenda for computing in finance addresses technical and strategic demands that can be met by adopting a broad foundation of computing drawing on a suitable framework for deploying prevailing computing practices and leveraging novel uses of the computer within this framework. Technical demands take into account the experiential and the human factors, and the pervasive[1] *emergence of computing. Strategic demands take into consideration qualitative uses of computer-based technology to support diverse real world activities that are cognitive rather than operational, such as decision support, business process modelling, learning, management, interpersonal communication, etc..*

Motivating the paradigm shift at the computational level

Addressing the wider agenda of computing motivates a paradigm shift at the computational level that involves a reconstruction of the software system development activity in a wider framework capable of addressing technical and strategic demands. This involves the emphasis on amethodological, situated and human centred approaches to software system

[1] This factor refers to the application of computer-based technology in various devices including interactive TV, mobile phone, etc.

development that favour user-developer-designer collaboration in distributed modelling of a broader view of a system where human role is central.

EM applications and prospects in finance

The main contribution of the thesis has been to propose several applications of EM in finance and to provisionally evaluate their prospects. In particular I have shown how EM technology can potentially address the wider agenda of computing in finance by:

i. *considering software integration in the financial enterprise as a social and technical activity. A situated integration model emerges drawing key principles for software integration taking into account the interaction of various human and electronic agents*[2].
ii. *considering virtual collaboration in the financial enterprise as a situated context dependent activity within a social network where every participant has its digital and non-digital information horizon. This motivates greater flexibility, adaptability, and human integration in the development of virtual environment for collaboration.*
iii. *providing a computer-based support for the shift from the old to the new trading model. This consists of developing a computer-based artefact The Open Financial Market Model (OFMM). The construction of this artefact takes into consideration various factors including:*
    - *experiential rather than formal approaches to knowledge construction*
    - *the role of agency and observation for a richer description of interaction in the financial market*
    - *the semantic relationship between the computer-based artefact and the real world financial market context*
    - *openness*
    - *flexibility*
    - *modellers' subjective personal insight and perception*
    - *a closer integration between the computational activity and various financial market related activities including: learning, decision support, modelling the trading process, etc..*
    - *semi automated activities*
    - *collaboration amongst modellers involving the sharing of private / subjective and public / objective perspectives*
    - *evolving requirements engineering*

iv. *supporting computer mediated interpersonal interaction in financial engineering through the communication of definitive scripts and the creation of the context of interaction based on agency and dependency. This takes into consideration:*
   - *the role of agency (privileges to take actions) in the communication*
   - *the diverse modes of interaction*
   - *the collaboration of participants in a classroom or practitioner use context.*

v. *considering the need of a closer integration of the software system development activity and the financial research development cycle. This draws on:*
   - *amethodological non-structured approach to software system development and a situated account of the financial research development cycle (FRDC)*
   - *user (financial expert) – developer (programmer) – designer (financial expert) collaboration*
   - *a holistic view of the financial research development cycle based on modelling rather than programming*

The above preliminary findings foresee a promising role for EM technology in the finance domain. This encourages the adoption of the principles of observation and experimentation to construe financial market phenomena to complement current existing approaches. With the openness and situatedness of the software system development activity adopted within the EM framework, the designer (financial expert)-developer (computer expert)- user (with general expertise) as well as different financial market participants guide the evolution of the financial system in response to change and to their experiential knowledge and insight in understanding the change. In this manner, the financial and computational activity integrate more coherently, while preserving the role of different participants and respecting their domain knowledge.

[2] The term agent refers to entities capable of inducing state change to the integrated system.

9.2 Research Limitations

In considering a wider agenda for computing in finance (enterprise, market, and investment levels) some research limitations need to be acknowledged. These are attributed to three factors: time and resources, technology support, and research infrastructure.

- Time and resources: every research has time and research limitations. The author acknowledges that more practical work should be undertaken to further support the application of EM technology in the case studies considered viz: software integration; virtual environments for collaboration; the open financial market model (OFMM); data intensive financial analysis in general and the Ho case study in particular; modelling financial instruments in general and the affine term structure model in particular.
- Technology support: every technology has its own limitations, including the proposed EM technology. In general, technology limitations can be attributed to three gaps: the gap between the principles / foundations and the techniques of the underlying technology; the gap between the techniques and the features of the tools implementing the techniques; the gap between the principles / foundations and the corresponding tools. These gaps are apparent in virtual reality (VR) technology, artificial intelligence (AI) technology, Object Oriented (OO) technology, and Empirical Modelling (EM) technology.
- Research infrastructure: the author faced a lack of supporting infrastructure to conduct the research at an academic and practitioner level.

The following paragraphs elaborate on each of these limitations, detailing where possible the essential reasons for these limitations.

Time and resources limitation

This research has aimed at investigating the potential application of the Empirical Modelling technology to the finance domain. Time and resources constraints imposed some limitations on the thesis:

i. Focusing upon the thesis aim, some aspects of the EM technology and the finance domain were overlooked:

EM technology has great prospect of application in the area of geometric modelling, engineering design, and computer aided manufacturing. These areas of applications of EM

were not sufficiently addressed in the thesis, especially the area of geometric modelling which could have enriched the development of the OFMM.

ii. The title of the thesis suggests applications and prospects of EM technology in finance. The considered applications and the foreseen future prospects of EM technology in finance could be further supported. Where principles and foundations are proposed such as in the case study of software integration, virtual environments for collaboration and the OFMM, more practical work can be undertaken to support these principles. Where a potential prospect of EM technology is emerging, further theoretical and technical work is needed.

iii. This research has not involved a detailed comparison of the EM technology with other technologies used in the finance domain. Although a background review of the application of different technologies in finance is provided in chapter 2, the application of these technologies to particular areas in finance is not compared explicitly with the application of EM technology to these areas.

iv. Industry contact is essential for the validation of the application of a particular technology to a practical domain, like finance. The author made several academic contacts in the field of financial studies, but did not pursue many industry contacts.

The technology limitation

In [BWM01] several limitations of EM tools are acknowledged. EM tools serve as a proof-of-concept for the application of EM principles in many different domains. EM tools need better visual interfaces, additional script management features, enhanced end-user computing, enhanced data storage capability, and further integration with other technologies such as VR and web technologies.

Further research is needed to assess the qualitative and quantitative contribution of EM technology to different fields of study.

EM literature does not direct much attention to key management and planning concepts such as optimum resource allocation (budget, time, personnel). Speed, efficiency, low cost, professional design are not major themes in EM technology. This fact makes EM technology more suitable at an academic and research level. For industry penetration and approval, Empirical Modelling technology should integrate resource management in its application to different fields of study. Conventional technologies are predicated on optimization, so that addressing optimization is strongly connected with relating EM to conventional computational approaches [ABC95].

Within the Empirical Modelling Framework, the boundary of the development process is not limited. This is an advantage and a disadvantage at the same time. It is an advantage because the development of software or products will always benefit from evolving knowledge. The disadvantage is that the product being developed might never reach a final stage and cannot be optimized for unspecified functions.

Limitation of the research infrastructure

The research has been inhibited by a lack of a supporting research infrastructure, both at an academic and practitioner level. As mentioned in earlier chapters, the computer implementation of different techniques and methodologies used in financial research is rarely documented in the research itself or separately. This can be mainly attributed to the importance of result reporting and analysis in finance, which takes precedence over the computer implementation. Financial experts are not much concerned to reveal their adopted technology support as this will not give any value added to their results and inferences. AI technology is currently a pioneer technology in bridging the gap between financial analysis and computer support to this analysis. The trend is towards more mechanisation of the financial reasoning process, and towards trying to treat information related to financial markets in a similar way to the results from experiments in a physics laboratory. Methodology, performance, and speed come first in the agenda for the use of the computer in finance. Experiential knowledge, situated activities, semi-automated activities are not yet explored in the domain of the application of IT in finance. This fact makes the research harder, as it is attempting to give greater weight to links between the domain of computer and finance that favour the social and situated aspect of the financial discipline. Though these links exist, they have not so far been given much consideration.

9.3 Further Work

In exploring the application of EM technology to the finance domain, five case studies are considered. The theoretical and practical application of the EM technology to each of the considered case studies can be reinforced along the following guidelines:

(1) The Situated Integration Model (SIM):

In addressing the problem of the integration of ERP and e-commerce application, the Empirical Modelling approach can meet short-term and long-term integration requirements:

In the short-term an SIM as introduced can potentially complement orthodox approaches to integration in many ways. Our proposals draw upon previous research into the role of EM in software development that, in particular, examines how:

- agent-oriented analysis combined with ISM construction assists program comprehension and the understanding of requirements (Sun et al., 1998);
- software modules can be extracted from ISMs and, if necessary, optimized by translation into conventional procedural programs (Allderidge et al., 1998).
- definitive scripts provide a powerful means of data integration that can be used in particular to express the way in which low-level redefinition can entail high-level change. Data conversion agents that are empirically tuned to particular patterns of synchronization can serve as databrokers (Beynon,2000).

In the long term, Empirical Modelling can potentially support the software engineering task in finding the appropriate technology for integration. This involves the identification of new concepts and abstractions for the presentation and processing of data, files, directories at a system level. An ongoing research along this line is initiated by Cartwright [Car99] in developing the Java Maintainer[3] (JAM) application interface (API) with the aim of porting EM principles of agency and dependency to the system and objects level.

[3] JaM provides a generic dependency maintenance system for use in object-oriented programming. It also provides facilities for organising the information in a dependency structure into virtual directories and manages user and group permissions to access and modify the data and dependencies. JaM' s dependency maintenance can be considered as a generic spreadsheet in which the *cells* of the

(2) The EM – VR merge

Chapter 6 suggests future prospects for the EM - VR merge in developing virtual environment for financial trading. EM technology motivates a new perspective on the design, application and use of VR technology in modelling a social context, such as the financial trading one. Further research on the prospect of the EM-VR merge is strongly advised. The aim is to identify a suitable computational framework for using VR technology in developing virtual environment for financial trading, modelling the financial trading process, supporting the financial decision making activity, and designing interfaces for virtual environments for financial trading. Qualitative and quantitative performance metrics[4] are needed to assess the distinctive qualities of model building within an EM-VR framework.

(3) Evaluation of the contribution of DEM to a wider computer-based support for the financial engineering activity:

The use of DEM in re-engineering the spreadsheet interest rate model introduced in chapter 7 suggests a potential for DEM to contribute to a wider computer-based support for the financial engineering activity that goes beyond the implementation of the mathematics of the financial model to provide support for group learning, group decision making and shared modelling. This is mainly attributed to the role of DEM in de-centralizing the spreadsheet modelling activity and extending its openness at the network level. The decentralization of the spreadsheet modelling activity involves the accommodation of various participants with diverse styles and privileges of action. The openness of the spreadsheet modelling activity at the network level involves: first the support of the distributed spreadsheet modelling with views that metaphorically represent the working space of each participant; and second the use of open ended communication of definitive script that extends endlessly the interaction of participants beyond features provided by their views. This communication does not need to follow any preconceived pattern or sequence.

It is essential for future EM research to develop ***conceptual*** and ***practical*** approaches to assess its contribution to widening the computer-based support of the financial engineering activity, and its added value in decentralizing the spreadsheet modelling activity and extending its openness at the network level to achieve a greater support for group learning among a network of financial academics.

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spreadsheet are instances of any class chosen by a developer that implement an interface of the API, not just conventional types of dates, strings and numbers.

[4] [MBG01] suggests cognitive dimensions [Gre00] to assess the potential benefits of VR modelling in a social context.

- At a ***conceptual level***, means for such assessment can be developed through further research on the use of Interactive Situation Models for cognitive aspects of user-artefact interaction [BRWW01] in a financial engineering context.
- At a ***practical level***, the assessment may involve the recording of *quantitative* and *qualitative measurements*. *The quantitative measurements* aim at assessing an improvement at the *operational level* including: ease of use, accessibility, greater interaction and engagement of the human with the computational activity, and enhanced management of the results of the computational activity. The *qualitative measurement* aims at assessing an improvement at the *cognitive level* such as the achievement of a learning objective.

  - *Quantitative measurements* can be recorded experimentally. This may involve (in case of the use of the spreadsheet interest rate models by academics) splitting a class into two groups: the first group interacts with the spreadsheet interest rate model; while the second group interacts with the re-engineered DEM version of this model. Recording techniques may include video recording or relying on human observers who might observe the details of the interaction of the students and the teacher with both versions of the model. Details of interaction, recorded in the course of observation, may include the frequency of changing the parameters of the model, the communication among students and teachers of various changes to parameters of the model, patterns of teacher / student interaction, the control of the teacher over the modelling activity undertaken by the student (dictating its pattern when necessary), etc..

  - *Qualitative measurements* aim at assessing a learning objective and can be recorded by inviting the participants in the modelling activity (students in each of the two groups formed as described above) to write an essay or fill-in a questionnaire that reflects their understanding of the financial concepts conveyed by the model. Evidence of better meeting a learning objective emerges through comparing the median/average grade of essays / questionnaires filled-in by students of each group.

(4) EM for data intensive applications

The thesis suggests that prospects for the EM technology for data intensive application can be enhanced through further research on data referencing, processing, and interpretation. This equips EM technology with means for visual exploration of large data sets that can support qualitative analysis of data intensive application domains such as finance. Such a qualitative

analysis provides value-added advantage over quantitative analysis by supporting experiential knowledge construction, human insight, and amethodological exploration.

(5) Support of different modes of interaction in interpersonal communication in domain specific activities

The thesis suggests complex modes of interaction in computer mediated interpersonal interaction in the course of the financial engineering activity. There is sign for further research on providing a suitable framework supporting diverse forms of interpersonal interaction with various modes of agency and roles for participants in domain specific group social activities. This would extend the research undertaken in [Son93] and [Sun99].

This thesis is an initial contribution to applications and prospects for EM technology in finance. Given its broad covering of the literature in the finance and computer science domain, its overview of almost every aspect of EM technology, its tackling of major problems pertaining to the different divisions of finance, this thesis provides a solid background for further research of the application of EM technology in finance. Pursuing the case studies considered is highly advocated as they are typical case studies encountered in the field of finance.