Novel Software System Development For Finance

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Abstract. This paper addresses the need for novel software system development (SSD) practices in finance. It proposes Empirical Modelling as a novel approach for SSD in finance [1]. This approach aims at finding a suitable framework for studying both the traditional and the emerging computing culture to SSD in finance. First, the paper studies the change in the financial industry and identifies key issues of the application of computer-based technology in finance. These key issues are framed in a wider agenda for computing in finance. Second, the paper motivates a paradigm shift at the computational level to meet the wider agenda for computing in finance and overviews the distinctive qualities of model building in EM that are of particular relevance to this wider agenda and that can potentially support a paradigm shift at the computational level. Third, the paper considers four case studies that reveal how EM technology can provide a framework for SSD in finance: in the financial enterprise, in the financial market, for financial engineering, and for financial analysis. The paper concludes with the need for new paradigms for SSD adaptable to domain specific needs.

1. Introduction

The financial industry is witnessing major changes. The financial enterprise is undergoing major business process renewal accompanied with the introduction of new technologies including electronic commerce; the financial market is shifting from an old to a new trading model that introduces major structural changes to the market and new roles for market participants; investment offers access to ever larger repositories of financial information and a wider choice of financial instruments to fulfill rising needs and expectations. In all these developments, there is a central role for human intelligence that can potentially influence the pattern of change and direct appropriate decisions in adapting to change. There is also a vital need for computer-based technology to support this human activity.

The relation between human and computer activities in classical models for computer-based support is characterised by rigidity and framed patterns of interaction. The emphasis in such models is on automation, not only in respect of routine trading operations, but even of the role of market participants. An alternative culture is emerging through the use of advanced technologies incorporating databases, spreadsheets, virtual reality (VR), multi-media, and artificial intelligence (AI). There is an urgent need for a framework in which to unify the classical culture, in which mathematical financial modelling has a central place, with the emerging culture, where there is greater emphasis upon human interaction and experiential aspects of computer use. This paper addresses the problem of developing software that takes into account the human factor, the integration of the social and technical aspects, human insight, the experiential and situated aspects, different viewpoints of analysis, a holistic rather than an abstract view of the domain of study, cognitive rather than operational activities, and group social interaction. The ultimate aspiration for this work is to transform the computer as it is used in finance from an advanced calculator to an 'instrument of mind'.

Meeting the challenges of software support for finance is not only a matter of deployment, but also of software system development (SSD): this motivates our focus on the potential applications and prospects for an Empirical Modelling (EM) approach to SSD in finance. EM technology is a suite of principles, techniques, notations, and tools. EM is a form of situated modelling that involves the construction of artefacts that stand in a special relationship to the modeller's understanding and the situation. The modelling activity is rooted in observation and experiment, and exploits the key concepts of observables, dependencies and agency.

First, this paper addresses some key issues of the application of computer-based technology in finance. Second, a wider agenda for computing in finance is motivated to meet the technical and strategic demands of the application of computer based technology in finance. Third, the principles and qualities of EM as an approach to SSD are overviewed. The suitability of EM as a framework for SSD in finance is then discussed with reference to case studies drawn from the finance domain (the financial enterprise, the financial market, financial engineering, and financial analysis). In particular, EM contributes: principles for software integration and virtual collaboration in the financial enterprise; a novel modelling approach adapting to the new trading model in the financial market; computer-based support for distributed financial engineering; and principles for a closer integration of the software system development (SSD) and financial research development (FRD) activities.

2. Key Issues of the Application of Computer based Technology in Finance

This section considers key issues of the application of computer based technology in finance: in the financial enterprise, in the financial market, for financial engineering and for financial analysis.

2.1 The Financial Enterprise

Key issues of the application of computer based technology in the financial enterprise are centered around integration in all its forms including: software integration, the integration of human and computing activities, and the support of group social activity through virtual collaboration. This is motivated by the need to provide a coherent integration of enabling tools and technologies for turning information into knowledge shared across the enterprise.

Software integration is currently challenged by the diverse functionality of the software to be integrated, and the need for novel SSD that can meet the technical and the strategic demands of this activity.

Providing computer based support for virtual collaboration in the financial enterprise is challenged by: 1) the need for novel SSD for virtual collaboration that takes into consideration customization, the integration of electronic and human activity, and adaptation; 2) the need to overcome the limitations of traditional approaches to SSD for virtual collaboration that constrain interaction between humans and electronic devices to patterns that guarantee a very high level of consistency; and 3) the need to address technical and strategic demands of virtual collaboration.

2.2 The Financial Market

Computerisation is about to overtake markets that traditionally depended on physical presence to bring buyers and sellers together in one place. There is a shift from an old to a new trading model. The old trading model involves a physical place, a central role for human intermediation, and lmited geographical spread. The new trading model involves straight-through-processing (STP), cross border trading, stock market integration, new roles for market participants; and the re-engineering of trading systems. There is an urgent need for models of stock exchange integration and enhanced operations and trading systems models. Stock exchange integration involves the integration of communication protocols, types of processing and trading systems. The models for enhanced operation include transaction models, STP models, and cross border trading models.

A key issue of the application of computer based technology in the financial market is to provide computer based support for the shift from the old to the new trading model.

2.3 Financial Engineering

Key issue of the application of computer based technology in finance is the support for SSD for financial engineering that takes into consideration the essential aspects of this activity. This would ultimately aim at widening the contribution of the computing activity beyond the implementation of the mathematics of the financial model to provide support for group learning/ group decision support/ and shared financial modelling.

In fact, computer based support for financial engineering is not only the implementation of a mathematical model but also involves: the support for a network of practitioners, the support for a network of academics; and the support for a complex distributed activity in the financial enterprise

2.3 Financial Analysis

Key issue of the application of computer based technology for financial analysis is to provide computer-based support to the Finance Research Development Cycle (FRDC) that is better adapted to the situated nature of this real world activity. This is motivated by the need to overcome the challenges/limitations of prevalent computer based support for financial analysis. Four challenges / limitations are to be addressed:

1) The lack of adequate reporting on computer based support for financial analysis.
2) The limitation of computer-based support in financial analysis to the implementation of algorithms and to data processing.
3) The limited benefit from emerging technologies in supporting the FRDC.
4) The adoption of structured approaches to financial analysis that might not deliver the proper intended financial analysis support.

3. The Wider Agenda For Computing in Finance

Key issues of the application of computer-based technology in the finance domain (in the financial enterprise, the financial market, for financial engineering, and for financial analysis) suggest a wider agenda for computing in finance that addresses technical and strategic demands. These technical and strategic demands 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 computer within this framework.

Technical demands take into account the experiential and the human factors, novel distributed computing practices, novel SSD practices, the integration of manual and automatic activities; and the pervasive 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 learning, decision support, business process modelling, re-engineering, management, interpersonal communication, etc..

The broad foundation of computing aims at providing a framework for developing software that takes into account these technical and strategic demands.

Addressing the wider agenda for computing in finance motivates a paradigm shift at the computational level that involves:

- A reconstruction of the software system development activity in a wider framework.
- New uses of computer that support cognitive and operational activities.

- Greater integration between the computer based activity and activities in the real world. Such integration provides computer based support for tackling domain specific needs.

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. The wider agenda for computing 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.

4. Empirical Modelling: An Overview

This section briefly overview Empirical Modelling (EM) [2] as: (1) a suite of key concepts, tools, techniques, and notations; (2) a modelling activity with distinctive characteristics; and (3) a technology capable of meeting the requirements of a wider agenda for computing in finance by introducing a paradigm shift in SSD practices and applications. Such a paradigm shift enables a closer integration between the computational and real world activity.

4.1 The EM Suite

Key concepts in EM are observables, dependencies, agency, agent oriented analysis, and definitive representation of state. An observables is an entity that has counterpart in the real world. A dependency represents an empirically established relationship between observables. An agent in EM is an instigator of change to observables and dependencies. An agency is an attributed responsibility for a state change to an observable. An Agent oriented analysis refers to an initial analysis of interaction between agents based on basic perception of observables. Empirical Modelling technology focuses on state representation. State in EM is represented by means of a system of definitions. Transitions from state to state are performed through redefinitions.

the LSD notation is introduced to represent explicit protocols and stimulus-response patterns that are characteristic of agent interaction. An LSD account is a classification of observables from the perspective of an agent, detailing where appropriate: the observables whose values can act as stimuli for an agent (its oracles); which can be redefined by the agent in its responses (its handles); those observables whose existence is intrinsically associated with the agent (its states); what privileges an agent has for state-changing action in terms of protocols and stimulus response patterns (its protocol).

The principal EM software tool developed so far is tkeden. The modeller viewpoint is represented by a script of definitions (a definitive script – EDEN script) resembling the system of definitions used to connect the cells of a spreadsheet. A distributed version of tkeden has also been developed: Dtkeden. It is implemented on a client-server architecture, in which the viewpoints of individual modellers are represented by independent definitive scripts executed on different client workstations. State changes are communicated between clients by sending redefinitions across the network via the server.

4.2 Model Building in EM

Model building in EM is a situated activity in which the roles of the modeller, the artefact, and the situation are inseparably linked, and leads to the construction of computer-based artefacts that stand in a special relation to the modeller's understanding and to the situation to which they refer. Model building in EM has several distinctive characteristics:

The semantic relationship between the computer based artefact and its real world referent

Empirical Modelling addresses the problem of the separation between experiences of the real world and of the computer-based model [3,4]. Such a separation may be less of a problem in scientific or engineering applications where theories and abstract entities can be successfully applied to certain extent. But in social and business domains such a separation leads to major problems. This stems from the difficulty of applying contextual information appropriate to different situations and the difficulty of end-users to modify the models.

The focus on state as experienced and the continuous human engagement in the modelling activity in EM implies a semantic relationship between the computer-based model and its corresponding real world referent. Such a semantic relationship can potentially support semi-automated activities where human input and agency is paramount.

The support of experiential knowledge construction

The concepts of observables, agency, dependency, definitive representation of state and agent oriented analysis in EM support experiential knowledge construction of an application domain by developing a computer artefact / a cognitive artefact based on construing a situation and constructing an associated Interactive Situation Model (ISM) [5].

In EM a system admits different construals, each formed based on a situated judgement. An Interactive Situation Model (ISM) is developed to explore different construals. Unlike a closed-world computer model with a fixed interface, an ISM is always open to elaboration and unconstrained exploratory interaction. States within the ISM metaphorically represent pertinent situations from the application domain, and possible transitions between states are explicitly constructed so as to be consistent with the developer's construal of a system in terms of agents, observables, and dependencies.

The communication of definitive scripts in distributed modelling

Modelling the real world as seen in the eyes of an external all-powerful human modeller has many drawbacks. These stems from several factors: i. the individual bias in the modeller's understanding and interpretation of phenomena in the real world; ii. the load on the modeller who is supposed to play the role of all agencies affecting the state of the model; iii. the lack of realism in the modelling activity; and iv. the foregone benefit of group social activity in modelling.

The Distributed Empirical Modelling (DEM) framework [6] aims at overcoming the limitations of centralised modelling by supporting collaborative distributed modelling. This can potentially serve four objectives: i. to redress the individual bias in the modelling activity; ii. to restore the balance in the modelling activity by inviting every agent (human and / or automatic) to take his/her/its role in the modelling activity through appropriate views and privileges of actions and modes of interaction; iii. to bring more realism to the modelling activity by involving every participants in the real world domain; and iv. to benefit from sharing insight and understanding in group social interaction.

4.3 Paradigm Shift in SSD in EM

Empirical Modelling Technology motivates a shift in emphasis in the software system development activity from programming to pervasive agent-oriented explanatory modeling [1].

The traditional software development cycle involves five stages: requirement analysis, specification, design, implementation, and verification. Modelling activity takes place in the requirement engineering, analysis and design phases, whereas the programming activity is involved mainly in the implementation stage. These two activities are fundamentally different in character. This stems from the fact that the modelling activity is more closely related to the real world domain and involves more human insight and input, whereas the programming activity assumes a detachment from the real world and a reliance on abstraction and circumscription.

There are two significant differences between Empirical Modelling and traditional modelling for SSD:

- In EM, the computer-based artefact exists prior to what would serve in traditional modelling for SSD as a point of circumscription.
- In EM, the modelling activity can carry on beyond what would serve in traditional modelling for SSD as a point of circumscription, in effect taking the place of the programming activity.
- In an EM approach to SSD, the artefact reflects the distinctive qualities of EM. These give the artefact an explanatory and agent-oriented character.

EM technology proposes an amethodical approach to Software System Development [6]. This approach has six features:

- The proposed software system development process consists of a collection of situated activities that arise in the construction and use of the required system in the real world.
- There is a greater focus on the interaction between human agents involved in the software development process and the product-under-development.
- The product under development is represented by an interactive artefact (ISM) that reflects the evolving software system.
- Both technical and social aspects are taken into account.
- An open-ended analysis of a domain is adopted. This informs the development of a system with dynamic rather than rigid boundaries.
- Deriving useful systems from an EM model necessitates an appropriate circumscription of the model once a desired functionality can be relied upon. However, the boundary of the system need not be preconceived, but can grow as the modellers' understanding develops.

5. Case Studies

This section considers four case studies that reveal how EM technology can provide a framework for SSD in finance: in the financial enterprise, the financial market, for financial engineering, and for financial analysis

5.1 Novel SSD for the Financial Enterprise

5.1.1 Software Integration

It is plausible to claim that the essential characters of SSD in EM are of particular relevance to SSD for software integration and in particular for meeting the technical demands of software integration [7]:

- The consideration of SSD in EM as a human activity that needs technical support is suitable for taking into account the technical and social aspects of software integration. The technical aspects of software integration relates to data and operation on data, while the social aspects relates to the modes of interaction of human agents accessing the data as well as the context of interaction in the software integration activity.
- The consideration of SSD in EM as a highly associated with its situated context is of particular relevance for taking into consideration the situated and context dependent nature of the software integration activity.
- The importance of the role of human agents in SSD in EM is of particular relevance to take into consideration the role of human agents in software integration and the modes of human agency that mediate and synchronize state changing activities.

An EM approach to SSD in the financial enterprise suggests the construction of a Situated Integration Model SIM to complement conventional approaches to software integration. Prevalent approaches to software integration involve creating a metadata repository comprising profiles of each of the different applications to be integrated (each profile is compiled from existing documentation and from the results of manual or automated code analysis) and the use of suitably engineered Common Information Models. The metadata repository supplies the resources from which the integrated system is to be developed. The EM approach to software integration involves three activities: i. the use of definitive scripts to express the way in which low-level redefinition can entail high-level change; ii. the use of ISM and its associated LSD for analysis that goes beyond abstract inputs and outputs to encompass the way in which interaction is embodied at the interfaces to other applications; and iii. the use of ISM and LSD to enable an experimental study of the modes of interaction between both existing software applications and those yet to be developed.

The SIM combines conventional and EM approaches to software integration that informs: possible modes of interaction, paradigms for integration, distributed and shared access to data, combined visual interfaces, synchronisation of data flow, and unified functionality.

5.1.2 Virtual Collaboration

It is plausible to claim that the essential characters of SSD in EM are of particular relevance to SSD for virtual Collaboration [8].

The consideration of SSD in EM as a social activity that need technical support is of particular relevance in meeting the technical demands of the coherent integration and/or correspondence of various activities. This involves the correspondence between:

- the computational activity and the human activity;
- the pattern of interaction and agency in electronic component and those in the external world;
- interaction through an interface and the interaction with the external environment;
- state and the external situation;
- the human intervention and the computer automation.

The consideration of SSD in EM as highly associated with its situated context and the central human role in the SSD activity are of particular relevance in meeting the technical demands of adopting situated and context dependent SSD practices and in meeting the strategic demand of considering virtual collaboration as bounded by the human information behavior (HIB) [1] and information horizon of participants [9].

The central role of interpersonal interaction in SSD in EM is of particular relevance to SSD for virtual collaboration. This can help in meeting the strategic demands of supporting interpersonal interaction and the technical demand of supporting diverse modes of interaction and agency.

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[1] D. H. Sonnenwald (1999) discusses human information behaviour with reference to three basic concepts: the context (the general setting within which an individual's interactions take place), the situation (a particular setting for an interaction within a context) and the social network (defined by characteristic patterns and resonances of interaction between individuals within a context). The ***information horizon*** is defined by the variety of information resources upon which an individual within a social network can draw.

It is of particular interest to highlight the essential aspects of the correspondence between the HIB and information horizon and the use of ISM and LSD in software development. Observables in an ISM have counterpart in the real world and are highly associated with the context of collaboration. The state of observables in the ISM corresponds to a special focus or a situation in the collaboration activity. The agency and dependency in an ISM corresponds to the semantics relationship between the digital and non-digital information horizon of individuals. The HIB is explicitly represented in an LSD description and implicitly represented in the interaction with the ISM

At a practical level, the use of LSD description and ISM in the exercise of modelling the Retail Trade Process in NYSE serves the purpose of representing the HIB of financial market participants in the retail trade explicitly and implicitly. The ISM and its associated LSD assist in exploring various scenarios and singular situations that might arise in the course of communication and interaction of human agents with programmable components and devices. Modelling collaboration in an online trading environment as a workflow of independent tasks undertaken by human and electronic agents fails to reveal the subtle issues associated with the trade process (e.g. singular situation.)

5.2 Novel SSD for the Financial Market

It is plausible to claim that the distinctive qualities of model building in EM meet the technical and strategic demands for modelling the financial market and supporting the shift from the old to the new trading model.

• *Representing state as experienced in EM meets the technical demand of experiential knowledge construction, and the strategic demand of understanding the trading environment and the behavior of market participants.*

The true price is a typical example of something that is not represented most effectively by a numerical value, as its meaning is arbitrated by agency and interaction. Relevant agents influencing the state of the true price are buyers, sellers and dealers, as well as external factors such as supply and demand. The true price can be construed as well in various ways: (1) as that value about which dealers can most profitably pitch their bid and ask prices so as to maximise trading throughput; (2) as influenced by supply and demand; (3) as expressed through responses of buyers and sellers to situation; (4) as influenced by the roles of informed and uninformed buyers; (5) as sensitive to potential dealer's influence and their motivation for being able to "estimate true price"; (6) as sensitive of external factors beyond the control of buyers and sellers.

A definitive script can be used to model the impact of the behavior of market participants on the true price of the security as an empirically established dependency relating the true price to various observables in the model. The empirically established dependencies may relate the true price of the security to the bid/ask/spread set by the dealer, the supply and demand, buyers and sellers rush, the roles of informed and uniformed traders, the dealer’s estimation of the true price, as well as external factors beyond the control of buyers and sellers. The ISM and LSD help in the exploration of various construals in the modeller’s mind about the factors determining the true price of the security. This exploration is expressed explicitly in an LSD and implicitly in the course of interaction with the ISM. Different construals can be explored to gain understanding of a trading behavioral impact, market efficiency impact, time duration impact, and market transparency impact on the determination of the true price of the security. The LSD description frames the pattern of agency and dependency in the model, and an ISM serves as a medium to experientially explore such a description.

• *The semantic relationship between the EM artefact and its counterpart real world referent supports a technical demand of integrating a manual and automatic activity and meets a strategic demand of providing decision support to market participants.* An EM definitive script can be used in capturing an evolving dealer knowledge of the trader's behaviors in terms of various observables. These observables may include: the probabilities of buying and selling; the potential time of delay for decision-making of buyers and sellers; parameters to determine the density of trade; the number of buyers and sellers around; the duration buyers and sellers are willing to wait; the influence of the spread level on buyers and sellers behavior; and the correlation between the behaviour of buyers/sellers and the true price. The EM model can include parameters and potential dependencies to support the rich construals reflecting the behavior of traders and the complexity of the trading activity. These observable have counterpart observables in the real world and their existence in the model is provisional and subject to growth or reduction. These observables are related by empirically established relationships that determine the state of the model. The state of the observables in the model can be changed through new definitions / re-definitions. The semantic relationship is established as a correspondence between:

- the observables in the real world that determine the behavior of traders and the observables in the computer based model;
- the observables in the real world about traders' behaviors and the dependencies between observables in the computer based model;
- the change to observables in the real world affecting the trading behavior of investors and the new definitions or re-definitions introduced in the model to reflect the realized change.

• *The communication of definitive scripts in EM supports the technical demand of providing novel distributed computing practices, and the representation of diverse kind of agency in EM supports a strategic demand of re-engineering the financial trading process while taking into consideration cognitive and operational activities.* Adopting a general methodology for modelling the financial trading process is hardly realistic due to the situatedness of the social activity surrounding this process. Although a workflow description gives a high level view of the financial trading process special cases of situated and erroneous actions are not revealed. EM allows the representation of many kinds of agency in the financial market: open-ended, constrained, and circumscribed.

The communication of definitive script and the support of various modes of interaction and agency roles through views and privileges of actions in DEM meet the technical demand of providing support for distributing modelling of the financial market. For example, the agency role of the dealer and investor can be represented through provisional views including different observables and privileges to view and change the state of these observables

• *The distinctive qualities of model building in EM can potentially provide a computer based framework unifying classical and emerging software development practices and technologies. This meets the technical demand of providing support for new technologies in modelling the financial market.*
EM research aims at finding a suitable framework for deploying virtual reality (VR) technology in social application domains [10]. Such a framework takes into account the central human role, diverse role of agency and modes of interaction, and the manipulation of the semantic of suitable geometric metaphors associated with the human and agency roles as well as the various modes of interaction.

An EM approach for modelling the shift from the old to the new trading model suggests the development of an open financial market model. The aim of such a model is to establish a closer integration between the financial trading related activities and the computational activities. The users of an OFMM are developer/designers/users in SSD, market participants seeking decision support, and academics seeking a better understanding of the financial market and a learning objective. An OFMM serve as a physical artefact representing our personal and subjective construal of the financial market.

5.3 Novel SSD for Financial Engineering

It is plausible to claim that the Distributed Empirical Modelling (DEM) framework and technology meet the requirements of SSD for financial engineering.
The DEM framework relies on the theory of distributed cognition and ethnomethodology. In this framework modeller collaborate as internal agents shaping the state of the model through views and privileges of actions that are set by an external observer who creates the context of interaction. This framework supports collaborative modeling, and agency role gives modellers privileges to view observables and introduce change to the state of these observables. The DEM framework supports SSD that views financial engineering as a social activity involving a network of practitioners or academics and where interpersonal interaction is an essential activity. DEM technology provides technical support for distributed financial engineering involving diverse agency roles and complex modes of interaction. It provides a generalisation of the spreadsheet concept by: supporting agent roles and diverse modes of interaction; distributing the centralised spreadsheet modelling activity; and supporting openness of interaction.
For example, the DEM framework and technology supported the re-engineering of a spreadsheet interest rate model by maintaining the spirit of the spreadsheet model in term of dependencies between parameters of the model and by introducing the result of the observation of classroom interaction with the spreadsheet model [1]. These observations relate to agency and privileges of actions; modes of interaction; visualisation; and management of the modelling activity .

5.4. Novel SSD For Financial Analysis

It is plausible to claim that the paradigm shift in SSD in EM promises a closer integration between the finance research development (FRD) and the software system development (SSD) activities. Three problems in prevailing computer based support for financial analysis are addressed. These problems hinder a closer integration between the finance research development cycle (FRDC) and SSD, and are tackled by studying the suitability of the paradigm shift in SSD in EM to establish the aimed closer integration.

1. The first problem is the gap between the designer's knowledge of the meaning of the financial data set, and the abstract representation adopted by the developer to represent this data set in the program. This gap creates discrepancies between the state of the financial research and the state of its corresponding program. EM technology supports a paradigm in SSD from a developer centered SSD to User (Designer)/ developer collaboration in SSD. By considering FRD and SSD as social rather than merely technical activities, a closer integration between these activities is established. As such the programming activity is turned into a shared modelling activity.

2. The second problem is the mismatch between the stages of the FRDC and the stages adopted in a structured approach to SSD. There no direct one to one mapping between these stages. The five stages of the FRDC are data collection, data manipulation, the implementation of numerical and econometric methods, result reporting, and result interpretation. These stages do not map coherently with the seven stages of structured SSD (problem definition, feasibility study, analysis, system design, detailed design, implementation and testing)

EM technology supports a paradigm shift in SSD from structured, methodological, and abstract approaches to SSD to a situated, context dependent, amethodological approach to SSD that can better adapt to the situated account of the FRDC and its context dependent nature.

3. The Third problem is the limitation of the computer based support to the implementation, reporting and data processing stages. Prevalent computer based support to the FRDC including object-oriented (OO), artificial intelligence (AI), virtual reality (VR), and end-user programming do not offer support beyond implementation, result reporting, and data processing. The cognitive activity of the financial expert involved in data collection, manipulation, and results interpretation stages of the FRDC enjoys no automated support apart from routine data processing. This is despite the fact that this cognitive activity, if appropriately conducted and supported, would have great impact on the success and usefulness of the computer-based support. This emphasises the importance of modelling the FRDC in a more holistic manner.

EM technology support a paradigm shift in SSD from programming to pervasive agent oriented explanatory modelling. This paradigm shift can potentially provide a holistic view of the FRDC. With the adoption of an EM approach to SSD in this context, the modeller can bring understanding of human agency and potential computer agency to bear on the construction of a computer based artefact. Human agency relates to the cognitive activity associated with the choice of strategies for data collection and manipulation, the methodologies for financial analysis to be implemented, the style of result reporting that impact on the interpretation of results.

EM can potentially enable the modeller to embody these activities in an artefact without invoking circumscription. This allows the SSD to proceed (in a less constrained way and a greater potential for success) without premature commitment to a particular data management strategy, analysis methodology and reporting style. This feature, together with the agent-oriented qualities of the artefact and its explanatory character, potentially offer flexibility for experiment that can transform the scope for the modeller both to frame, and to adapt to, new requirements.

6. Conclusion

This paper has considered four case studies for the application of EM technology in finance. The main findings may be summarised as follows:

• K*ey issues for 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.

• *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.

• *A paradigm shift at the computational level* is needed to address the wider agenda for computing in finance. This involves a reconstruction of the software system development activity in a wider framework capable of addressing technical and strategic demands.

• *EM technology can potentially address the wider agenda of computing in finance by:*

1) considering software integration in the financial enterprise as a social and technical activity.
2) 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.
3) providing a computer-based support for the shift from the old to the new trading model. This leads to the construction of a computer-based artefact "Open Financial Market Model (OFMM)".
4) 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.
5) considering the need for a closer integration of the software system development activity and the financial research development cycle.

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.

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