Chapter 6

Emprical Modelling of The Financial Market

6.0 Overview

This chapter proposes an Open Financial Market Model (OFMM) for exploring and understanding the shift from the old to the new trading model. The OFMM aims at establishing a closer integration between the software system development activity and financial trading related activities. The latter activities include: understanding of the requirement of the new trading model, decision support, and modelling of the financial trading process.

Section 6.1 motivates the OFMM with reference to the challenges facing computer-based support for financial trading activities associated with the shift from the old to the new trading model. Section 6.2 proposes basic principles for developing the OFMM. Section 6.3 briefly reviews existing models drawn from academic and practitioner circles and takes one of them as the basis for a case study that can provide a proof-of-concept in respect of the technical implementation and uses of the OFMM. Section 6.4 proposes an EM – VR merge as a contribution towards a broad foundation of computing based on EM technology for addressing the technical and strategic demands of the agenda for computing in finance. Section 6.5 concludes with a summary of the key characteristics of the OFMM and the future prospect of EM technology in providing a closer integration of the software system development activity with the financial trading activity.

6.1 Challenges Facing Computer-based Support For the Financial Market

Trends in trading practice associated with the advent of virtual environments motivate a reappraisal of activities in the financial market domain. Relevant issues include: i. understanding the complex trading environment and the behaviour of its market participants, ii. modelling and re-engineering the financial trading process, and iii. providing decision support for market participants. These issues require deep domain knowledge and the choice of an appropriate computational paradigm.

i. Understanding the complex trading environment and the behaviour of market participants:

The financial market is a complex system involving many different participants (investors, brokers, dealers, market makers, floor specialists, etc.) and a large number of instruments meeting various financial needs and requirements. This makes software system development for the financial market a subtle and dynamic activity. Understanding the trend of various trading signals is difficult and requires profound knowledge of financial theories and practices. This is exemplified in three key activities:

(a) Assessing *the impact of the trading behaviour of different market participants and of the introduction of new trading systems on market prices and the role of different market participants:* The trading behaviour and the role of market participants shapes, and is being shaped, by the financial market microstructure (the execution system and the market information system). The shift from an old to a new trading model implies a new market microstructure and necessitates advanced approaches to understand and study the behaviour of market participants and its impact on the market.

(b) Identifying the constituents of transaction cost: Different estimations of the trading cost are found in the finance literature. The cost of trading a security is given as composed of two parts: an implicit[1] and an explicit[2] part. Haynes (2000) subdivided

[1] The bid-ask spread is the implicit cost of trading. The dealer, who acts as a broker, may charge no commission but collect the fee entirely in the form of the bid-ask spread. Another implicit cost of trading that some observers identify is the price concession an investor may be forced to make for trading in any quantity that exceeds the quantity the dealer is willing to trade at the posted bid or asked price.

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. It is difficult to find an exact formulation of the trading cost as many factors that cannot be exactly quantified or assessed contribute to it.

(c) Estimating the true price of securities: Like trading cost, the true price of a security is difficult to quantify in exact metrics. Theories in finance attempt to describe price movements in the market. They include the random walk and efficient market hypothesis, theories related to the determination of the intrinsic value of a security, and prediction and financial analysis theories and practices. A brief overview of these theories is given below:

- Prices in the markets follow a random walk[3] [BKM96]. This does not imply that trades are irrational. Randomly evolving stock prices are the necessary consequences of intelligent investors competing to discover relevant information on which to buy or sell stocks before the rest of the market becomes aware of that information. Randomness in price changes is different from irrationality in price changes. If prices are determined rationally, then only new information will cause them to change. Therefore, a random walk is the natural result of prices that always reflect all current knowledge. The notion that stocks already reflect all available information is referred to as the *efficient market hypothesis*. The general idea behind the three forms of efficient market hypothesis EMH[4] is that, except for long-run trends, future stock prices are difficult if not impossible to predict.
- Many theoretical foundations lie behind the determination of the intrinsic "true" value of the security. Firm foundation theorists view the worth of any share as the present value of all dollar benefits the investor expects to receive from it. In an attempt to answer two questions: what determines the real or intrinsic value of a

[2] The explicit trading cost is the commission paid to the broker. Two types of brokers are identified: full-service (providing full service including financial analysis) or discount brokers (provide no services other than buying and selling securities, holding securities, offering margin loans and facilitating short sales).

[3] A random walk is one in which future steps or directions cannot be determined on the basis of past actions.

[4] The efficient market hypothesis (EMH) introduced by Fama (1970 and 1991) is one of the central ideas in modern finance. There are different versions of the market efficiency hypothesis according to the information set that is assumed to be contained in market prices. In weak form efficiency, current market prices reflect all information on past prices. In semi-strong form efficiency current market prices reflect all publicly available information. Whereas, in strong form efficiency current market prices reflect both public and private information. Malkiel (1996) stated that a capital market is efficient if it fully and correctly reflects all relevant information in determining security prices.

share? and what are the so-called fundamentals that security analysts look at in estimating a security's firm foundation of value?, Malkiel (1999) identifies four determinants affecting share value: the expected growth rate, the expected dividend payout, the degree of risk, and the level of market interest rate. However, these four determinants cannot exactly reflect the true value of the security because expectations about the future cannot be proven in the present and precise figures cannot be calculated from undetermined data.

- Harris (1998) demonstrates algebraically[5] that informed traders make prices informative. The buying of informed traders tends to push prices up and their selling tends to push prices down.
- Ridley (1993), regards market trading as relying 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.
- Investors conduct two types of analysis to predict future prices: technical and fundamental. Technical analysis studies trends in historical charts to predict the future, and fundamental analysis attempts to estimate a true value of a security and buy and sell according to the difference between the market price and estimated true value of the security. The weak and semi-strong forms of the EMF raise doubts about the effectiveness of the technical and the fundamental analysis. However, investors still conduct both types of analysis to predict the market.

ii. Modelling and re-engineering the financial trading process:

A financial market model would aim at supporting the design of a better market by exploring current and potential market microstructures. Many factors are reshaping the financial market microstructure. These include globalization, integration, trade liberalization, monetary union,

[5] The algebraic illustration of how markets aggregate information considers n traders each producing a different forecast of the true value of the security. This forecast includes an estimation error factor. Assuming that the trader's desired position in a security is proportional to the difference between his/her forecast and the market price and that the security is in zero net supply, then the market price is computed by equating the sum of all desired positions to the net supply of zero. The market price is then equal to the average individual forecasts and the true price of the security is equal to the market price plus the average individual traders' forecast errors. As the number of informed traders get larger the market price will approach the true value of the security.

deregulation, and financial crises[6]. These factors are putting great pressure on financial markets to re-engineer their business processes and maintain a competitive position in a global market. Re-engineering the trading system demands a closer integration of the *trading process model* and the *financial analysis* adapted to the corresponding process model (cf. the figure below).

Trading System Re-engineering model

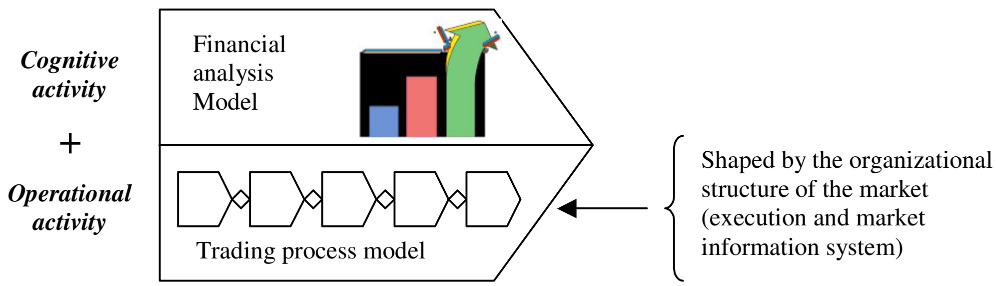


Figure 6.1 Integrating the trading process and the financial analysis models in the re-engineering model

Konana et al (1999) depicts the trading process in a transaction cost/revenue model tracing the workflow of an order directed from an investor to an electronic broker. The broker can then channel the order to a market maker or to a stock exchange. The aim of the model is to reveal the impact of the trading process on the implicit and explicit part of the trading cost. This provides a high level model of the trading process that bypasses the organizational structure of the market and its impact on the order flow and the transaction cost.

Harris (1998) introduced nine trading stories showing the different trading process models adopted in trading a particular type of financial instrument in a particular type of market. These stories include: a retail trade in NYSE, a retail trade in NASDAQ stock, an institutional trade in a NYSE stock, an institutional trade in a NASDAQ stock, a very large block stock trade, a cask commodity trade, an option market trade, a bond market trade, and a foreign exchange trade. We can infer from these trading stories that the price at which a transaction is executed and the behaviour of market participants are shaped by the trading process model and the type of instruments traded.

[6] *The crash of the New York stock exchange in the 1980's* -The largest stock-market drop in Wall Street history occurred on "Black Monday" - October 19, 1987 - when the Dow Jones Industrial Average plunged 508.32 points, losing 22.6% of its total value. That fall far surpassed the one-day loss that began the great stock market crash of 1929 and foreshadowed the Great Depression; *The Asian crisis* - In June-July 1997 the currencies of Asia started to fall. Without exception all Asian currencies have fallen [Tho97]. The impact of the Asian crisis was felt worldwide.

The trading process is highly influenced by the organizational structure of the market and the type of instruments traded. The latter two factors affect the price determination mechanism in the market and consequently the investor's analysis and forecast of the market. Describing a trading process can be approached in two ways: using a literal description or a business process model. A trading system re-engineering model is better targeted when integrating the trading process with the financial analysis conducted in a particular market.

iii. Providing decision support for market participants

In the face of highly competitive and changing financial market conditions, providing decision support to different market participants becomes urgent. It is difficult to devise a formal methodology that informs the decision making of a market participant. Understanding the complex trading environment (assessment of the impact of the behaviour of market participant on the financial market, the identification of the constituents of the transaction trading cost, and the estimation of the true price of securities) challenges formal methodologies in leading the decision making activity. Greater adaptability and flexibility is needed to support the decision making activity and the gradual knowledge construction.

6.2 The OFMM Concept

6.2.1 Motivations and aims of the OFMM

The previous section highlights various challenges that face computer-based technology in supporting the shift from the old to the new trading model. These challenges were revealed by a closer view of the various activities undertaken in the financial market domain. In this section, we explore the possibility of meeting these challenges by developing a novel kind of computer-based financial market model, to be called an open financial market model (OFMM), that promises greater support for the shift from the old to the new trading model.

Openness in the model is proposed at a conceptual and practical level. At a conceptual level openness connotes incompleteness of the model; its use for knowledge construction rather than representation; its ability to reflect growing experiential knowledge; its lack of circumscription; and the absence of a particular methodology to develop the model. Practically, the term 'open', used as an attribute for a model, refers to a high degree of flexibility in revising the state of the model through adding, amending, and discarding information.

In providing support for the shift from the old to the new trading model the emphasis is on modelling rather than programming. The term *model* differs from the term *program* and the term *software system*. Whereas a program has a specific behaviour usually described in terms of input-process-output, a model (in the sense of the term adopted in this thesis) aims at representing an evolving state. A system is an end product that can be derived from the model through an appropriate circumscription of the model once a desired functionality can be relied upon. It is assumed that the boundary of the eventual system is not pre-conceived but rather grows with the developing understanding of the modeller – in respect of both understanding of the domain and of the requirements for the system.

An OFMM aims at establishing a closer integration between the financial trading related activities and the computational activity, in particular the software system development activity. The model must be essentially open for two reasons: the growing complexity of the financial markets; and the limitations/incompleteness of financial theories to fully explain financial markets phenomena. The use of the model is not restricted to a hierarchy of users. It is open for use by:

- Designers - developers -users participating in the software system development for the financial market. The designer is the financial expert dictating the features and functionality of the financial software system. The developer is the technical expert in charge of constructing the software system meeting the designer's requirements. The user refers to the end-user of the financial software system designed by the financial expert and produced by the developer. This end-user might have some financial and computer knowledge however this is not essential. He / she uses the financial software system to fulfill an operational need or gain knowledge and understanding of the financial market.
- Market participants (brokers, investors, market makers, floor specialists) seeking decision support
- Academics cultivating experiential knowledge of the financial market

An OFMM refers to a physical artefact representing a personal and subjective construal of the financial market. The physical artefact is mainly computer-based, it is constructed experientially as opposed to formally, and its use is tailored to the modeller's insight and perception. It can be used for establishing a closer integration between the software system development activity and various activities undertaken in real world contexts such as learning, decision support, business process modelling. The model can be shared collaboratively to take account of both private/subjective and public/objective perspectives, to be more realistic, and to better serve group social activity.

An OFMM assists *requirements engineering*[7] in software system development for the financial market. It promises a finished product at some point in time. However, the conditions for the delivery of this product are difficult to preconceive in advance. This assumes that the requirements engineering is not only limited to an early stage of the software system development activity but spans the whole period of development.

It is not realistic to expect to construct a computer-based model of this nature with current technologies and limited experience of the highly changing financial market conditions. We focus instead on proposing basic principles for developing such a model. Three aims motivate the development of an OFMM:

- cultivating the understanding of financial markets phenomena and seeking an appropriate medium to convey this understanding and to communicate it across a social network;
- developing computer-based support that establishes a closer integration between the financial trading related activities and the software system development activity;
- better understanding and support for the shift from the old to the new trading model by developing a computer-based means to explore the new trading model and its impact on the financial market microstructure experientially.

6.2.2 Basic principles

The motivations and objectives of an OFMM introduced above highlight important considerations in choosing an appropriate computational framework for an OFMM. These include:

[7] Requirements engineering refers to the early phases of the traditional software system development cycle. As overviewed in earlier chapters, this development cycle consists of five stages (requirement analysis, specification, design, implementation, and verification). Software system development focuses on the process initiated in capturing the statement of the problem of a client and terminating with the delivery of the software product that will potentially solve the problem. Different computer aided software engineering CASE tools can be used at different stages of the software system development cycle.

- *The experiential dimension of the model building activity*: trends in trading (new trading styles, mixed virtual/real trading contexts, etc) oblige a richer account that conveys experiential knowledge which is difficult to gain through abstraction. Financial concepts admit rich and diverse construals. Such construals should be reflected in any financial modelling framework.
- The agency, observable agenda: financial market modelling requires a far richer quality of observation and agency description. This is of importance and particular relevance to the software system development for the financial market.
- Openness and flexibility: change in the financial market is rapid. This obliges the adoption of approaches to modelling admitting openness and adaptability that do not require wholesale model reconstruction.

Chapter 3 reviewed the distinctive qualities of model building in EM: a) the focus on state as experienced; b) the maintenance of a semantic relationship between an application domain and a computer-based artefact; c) the use of an artefact for knowledge construction; d) the support for collaborative relationships in distributed modelling. These qualities have broad implications for the software system development activity and its computer-based support in terms of openness, situatedness, and the absence of rigid methodologies. Modelling is central, and situated user-developer-designer collaboration is essential for cultivating the understanding of requirements. This points to the conclusion that EM provides a suitable basis for the development of an OFMM. This case is supported below through the consideration of a series of claims. Each claim is addressed by reviewing specific characteristics of the finance domain and by establishing a comparison with traditional computational paradigms when necessary.

Claim 1: ***Principles for experiential knowledge construction in EM can be adopted in developing an OFMM.***

Claim 2: ***Establishing a semantic relationship between an OFMM and the real financial market domain, following an EM approach, can potentially cope with major issues surrounding the new financial trading model. These include the estimation of transaction cost, true price determination, price movement, and the impact of the behaviour of different market participants on the trading activity.***

Embodied intelligence is an important concern in developing an OFMM as it determines the uses, scope, and evolution of the model. Knowledge is needed to perform intelligent (expert) tasks. Encoding knowledge in a model assumes completeness of this knowledge and is used for selecting an optimum solution for a problem. The question to be addressed is whether an OFMM should provide a fixed repository of encoded knowledge, a growing repository of encoded knowledge, or it should support knowledge construction in an experiential way.

EM technology aims at using the computer as an instrument that supports mental modelling. EM technology acknowledges the limitations of human thinking in solving problems in the real world domain. It attempts to support human thinking and decision making, where possible, without imposing a rigid framework shaping this thinking. EM technology takes account of the situatedness of the human thinking and common sense reasoning. In solving problems in the real world domain, EM technology considers the whole problem from a personal, subjective or shared objective view. A divide-and-conquer[8] strategy can be adopted, but the subdivision of problems and tasks is subjective and is made in response to personal or shared insight. EM technology does not assume complete knowledge of the real world problem domain; it attempts to construct this knowledge in an experiential way by interacting with the real world and a physical, typically computer-based, artefact. The key characteristic of this artefact is that its state is linked by a semantic relationship to the state in the real world problem domain and gradually evolves with the state in the real world. A state in EM is defined in terms of observables, dependencies, and agencies. EM supports the construction of knowledge about this domain.

AI technology, based on the physical symbol system[9] hypothesis, aims at using the computer as if it were a human brain. It ignores the limitations of human intelligence, assumes that human knowledge and reasoning are complete and correct, and proceeds to the next step of encoding human knowledge (referred to as knowledge engineering) about a problem domain for future use in exploring a solution space. In considering a complex real world problem domain, AI technology subdivides the activity of solving the problem into tasks and classifies these tasks as ordinary, formal, and expert tasks. From a technical point of view, AI technology adopts methodologies for knowledge management and solution search. The four

[8] A divide-and conquer strategy involves sub-dividing complex problems into smaller sub-problems and devising sub-tasks to solve these sub-problems.
[9] 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].

step process[10] in building an AI system assumes full knowledge about the system before building it and using it reliably in different situations.

Key issues raised in the application of AI to finance are knowledge representation, goals, and methodologies to solve problems in the investment domain. Abstraction, structuring, and model selection [TA83], the size of the problem space [NS72], its character, and the solution methodology in AI, all place economic limits on the scope of the problem that can be solved.

In knowledge-based systems, the solution space is defined by the way in which knowledge is represented. Trippi (et al, 1996) defines *knowledge representation* as the formalism for the systematic computer storage of facts and rules about a subject or speciality. Encoding knowledge in the knowledge base is referred to as *knowledge engineering*. Expert Systems are applied to routine financial decision making operations. The decision making process involves: identification of goals and constraints, generation of a set of feasible investments, formulation of alternative strategies, selection of an appropriate strategy, implementation of the selected strategy, and the explanation of results.

In developing an OFMM, a traditional AI approach would be directed towards building a knowledge base about such issues as dealer and investor expertise and true price generation. Knowledge about a dealer's strategic actions in response to trading flow can be encoded in an expert rule database that is consulted to determine the most appropriate action in response to a trade pattern. Such an approach is similar to the one used by Andrew Martin in developing a management information system (MIS) game [Mar00, MCB99]. Rules for the dealer's strategic actions in response to trade flow can be encoded in the knowledge base. Examples of rules are[11]:

```
IF ((estimated true price > ask) OR (informed trader rush to buy))
     THEN  raise ask
IF ((estimated true price < bid) OR (informed trader rush to sell))
     THEN  raise bid
IF ((spread == wide) OR (few uninformed traders are trading))
     THEN narrow the spread
IF ((inventory < -10,000 ) OR (inventory > 10,000))
     THEN adjust quotes to attract buy and sell orders appropriately
```

[10] (1) defining a problem in terms of input (initial situation) and output (acceptable solution); (2) analyzing the problem; (3) encoding the knowledge necessary to solve the problem; and (4) choosing the best problem solving technique to apply to the problem

[11] Rules encoded in a knowledge base are different from protocols in an LSD description. The key difference is that an LSD description reflects our initial understanding of the real world domain and is subject to amendment with our exploration of the real world domain and our interaction with the computer-based artefact (EM model).

The limitations of the knowledge based approach for developing an OFMM is revealed when attempting to encode knowledge about the true price determination and the rules for dealer's strategic action in response to his/her estimated true value of the security. Encoding rules for the determination of the true price of a security is a challenging task since the true price formation can be construed in different ways and in a situated manner.

Many researchers subscribe to the view that human knowledge is continuously growing in such a way that it cannot be circumscribed in a representation medium [Slo90, Cla97, Suc87]. Knowledge acquisition and construction is a continuous on-going process and cannot be limited in space and time. This undermines systematic approaches to knowledge encoding which assume a complete knowledge of the domain prior to the development of the AI system. Knowledge constructed over time requires extension or alteration of existing formal representations of knowledge. Abstract physical symbol systems used to represent reality might not always be adequate and may need refinement over time.

From an EM perspective, knowledge construction and knowledge representation are two complementary activities and both should be taken into account [Sun99]. Practically, definitive scripts are used to capture initial knowledge of the real domain, and re-definitions are used to introduce newly acquired knowledge. In constructing an OFMM, EM principles can be useful in construing a situation in the financial market context, and in capturing the state of this situation in a definitive script that can be used to realize and explore different possible construals.

> ***Claim 3:*** ***The adoption of an EM approach to situated collaborative distributed modelling in an OFMM supports semi-automated group decision making where human input and insight is central. This gives participants in the financial market greater potential in making decisions based on their constructed knowledge about key drivers in the financial markets, such as the true price of the security, traders' behaviour, transaction cost, etc..***

As discussed in earlier chapters, solving problems in the real world domain is a situated activity rather than a formal activity, especially on the first occurrence of the problems. Suchman (1987) argues that most plans (algorithms, strict laws, formal methods) are used by human agents as a resource rather than a source of control in every day life. This argument is also supported by the fact that a solution to a real world problem is context dependent, and human centred. However, a situated activity is error prone because it is human dependent, as compared to a formalised process derived from an engineering discipline.

In the context of the financial market, examples of situated activities are the dealer actions to adjust his/her quotes, and investors' actions to buy and sell shares. This situated activity is very human centric, because it relies heavily on the dealer's perception of the market and of trading flow.

Providing decision support to market participants (dealers, investors, market makers, etc.) in an OFMM raises the question of whether a fully automated or a semi-automated decision support system is adequate. A fully automated decision support system provides a solution to a well defined problem. The market participant does not intervene in the solution finding, apart from setting parameters in the input describing the problem and in framing the desired output. The resulting decision is either taken by the human participants or discounted in favour of a personal common-sense judgement. The semi-automated decision support allows the market participant to intervene in the process of identifying the problem and the solution space, and the exploration of a possible final solution. A semi-automated solution might not be the optimal solution as it is guided by human insight that might be erroneous and/or more limited than can be gained with automatic support. However, a semi-automated solution is more personal and subjective, it accounts for the constructed knowledge of the market participant, and is more likely to have an impact on the real decision making activity.

The decision making model in the dealer's mind might admit several components: bid/ask/spread quotes, the dealer position (inventory and profit), the buyer/seller flow, and his/her expectation of the true price of the security, etc.. In this respect, the dealer faces a dynamic problem, in which requirements (market making) and resources (inventory and profit) are changing over time. Automating the decision support process (problem identification, developing alternative solutions, and selecting solutions), as proposed by Mintzberg (et al, 1976) and Talluru (et al, 1983), confronts several challenges. The dealer might find a difficulty in identifying or formulating his/her problem in a circumscribed way. The dealer has two roles to play that might be contradictory in nature: making a market (maintaining a flow of buyers and sellers) and maintaining a profitable position. The problem of making a market is vast and difficult to circumscribe in a concise way as it invokes tacit knowledge and personal experience of a particular dealer in a specific market. Although it is easy to calculate realized profit through a mathematical formulation, there is no recipe for profit making. Making profit in the market depends on the skill and experience of the individual and on factors which are difficult to identify or judge, and where their contribution to profit is hard to assess. There might be no abstract or systematic solutions to ill-framed problems. As the problem of making a market and remaining profitable is not clearly formulated, it is hard to confirm that solutions respect the constraints of the problem. There is no point in delivering a solution for making profit to a dealer who cannot really quantify or formulate the level of profit to which he aspires, especially in adverse market conditions. There may be no explicit heuristic or algorithm for selecting a solution out of a set of ill-adapted solutions to a problem. The best amongst the worst solutions might look the most appealing.

The EM approach views decision support as a situated and experience based activity: It does not resort to full automation in the first instance, but favours semi-automation. Semi-automated decision support adapts to the evolving perception of the user. The aim of an EM model would be to complement and support the dealer's own conceptual modelling. Visualization plays an important role, and the dependencies between the components of the decision making model are numerous. Invoking Empirical Modelling technology in dealing with imprecise, qualitative problems in a way suitable for end-user development can support to a certain extent the decision making activity of the dealer. The dealer can conduct a what-if style of analysis or explore different scenarios by establishing or re-defining dependencies between the components of the model. Visualization can help in displaying the current state of the mental model of the dealer, and in making the state of the market transparent to the dealer in his own limited market view.

> ***<u>Claim 4:</u> EM technology supports an experience based approach to building an OFMM that can represent three kinds of agency in the financial trading. This can integrate cognitive support through open ended exploration of the finance domain and its corresponding trading process with operational support through depicting trading practice in specific markets. This might overcome the limitations of workflow description and structured methodological approaches in depicting the financial trading process and in exploring singularities arising in different trading practices in the financial market.***

Embodying the financial trading process model in an OFMM is important to support the understanding of the shift from the old to the new trading model. The questions to be addressed are: Is a formal description of the financial trading process sufficient to explore the new trading model? Is there a general methodology for modelling the financial trading processes? Would the integration of the financial trading process in an OFMM help in giving better support to the decision making activity of market participants?

Modelling the financial trading process does not merely aim at depicting a workflow but should help to explore in an experiential way singularities arising in a particular trading process. A workflow description, such as the one found on the web page of chapter 6 in the thesis web page on the Thesis CD, depicting the financial trading process in a retail trade at NYSE, doesn't support the exploration of singularities arising in the trading process but simply serves a documentary purpose. Exploring the new trading model is better targeted in a situated financial trade process model. Such a model grows from experiential interaction with the model and the real financial market and helps in capturing a business state as experienced. This state evolves over time with increased domain knowledge and is associated with many different foci of attention [BRR00-1].

Representing the financial trading process by an abstract pattern[12] does not reflect the actual experiences involved in carrying out the financial trading process. Abstract computational states and business rules refer to interactions and situations that are presumed to be so well-understood that they can be detached from the real trading context and used reliably without the need to refer to the real financial market context. This abstraction separates experience in the real world from the financial trading process. Such a separation would be more readily tolerated in scientific and engineering contexts where theories and abstractions apply with a high degree of reliability. But in a social context this abstraction might detach the model from the real world domain and makes it useless in exploring different non-preconceived situations. From an EM perspective an OFMM should be provisional, subjective, and situated, and include both formal and informal knowledge of a domain. An OFMM could also be regarded as a model of the finance domain. It is related to its subject domain by a semantic relationship that is established experientially. The understanding of the finance domain model and the exploration of the new trading model proceed in parallel with the development of an OFMM. An OFMM is typically computer-based. Interactive experience with an OFMM and the finance domain is mediated by metaphors. A virtual reality technology can better mediate interactive experience when supported with EM principles for development.

[12] An abstract pattern may be described from a computational perspective by a formal state transition model (e.g. stateshart or PetriNet), and from a business perspective by a collection of rules that define the role of human participants [BRR00-1].

As a model of the finance domain, an OFMM can represent many kinds of agency in the financial market: open-ended, constrained, and circumscribed. Open-ended agency can be modelled by what is characterised in [Bey97] as a ***View 1*** agent: a group of observables with object-like integrity[13] unexplored potential to affect the model behaviour. Examples of entities that can be appropriately modelled by open-ended agency are traders, investors, financial indicators, electronic trading, payment, and transfer systems, economic indicators, financial events and news, political events and news, etc.. Such agency can be realized through role playing of participants (e.g. traders) and devices (e.g. trading systems) by human agents, and through direct manipulation of environmental entities (e.g. financial indicators). It may also be appropriate to introduce additional observables to reflect enriched observation of the agent. Constrained agency can be modelled by what is characterised in [Bey97] as a ***View 2*** agent: a ***View 1*** agent to which is attributed some patterns of stimulus-response and a role in changing state. Examples of entities that can be appropriately modelled by constrained agency are the different types of order placed by an investor to buy or sell financial instruments from the market (such as market, limit, market if touched, good till cancel, fill or kill orders), the different types of trading sessions adopted in stock exchanges (such as continuous or call market sessions), and the different types of execution systems (such as quote-driven dealer markets, order-driven markets, brokered markets, or hybrid markets). Such agency can be realized through introducing rules that can be executed manually or automatically at the discretion of the modeller. Circumscribed agency can be modelled by what is characterised in [Bey97] as a ***View 3*** agent: a ***View 2*** agent whose stimulus-response patterns are entirely predictable and that has preconceived roles in changing state. Modelling of this nature is only possible "at the point of circumscription" in the sense introduced in section 4.1.2. Such agency is represented in a model of a specific trading process in a specific exchange, such as the retail trading process in NYSE or NASDAQ.

Adopting a general methodology for modelling the financial trading process is hardly possible 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.

Converting a financial trading process model into a software product for the financial market is not a straightforward task if the developer, designer and user are not involved in the initial

[13] In this context, object-like integrity refers to the coexistence of observables that is synchronized in time.

finance domain modelling and the conversion process. This can be largely attributed to the gap between the business and IT perspectives on modelling the finance domain [FRKBCJ00]. Participative process modelling is suggested in [CRB00] for the situated requirement engineering of an OFMM.

Integrating the financial trading process model with the financial analysis model in an OFMM can serve a better strategic decision support objective where the human market participant participates actively in the decision process.

> ***Claim 5:*** ***user-developer-designer collaboration enacted in distributed EM is essential in developing an OFMM. This can potentially deliver greater flexibility in the software system development activity of an application for the financial market derived from appropriate circumscription of an OFMM.***

Distributed interaction in an OFMM is needed to address three issues: user-developer-designer collaboration in the model development; group decision support; and participative modelling of the trading process.

The designer, the developer, and the user of an OFMM have a growing knowledge about key factors shaping the financial market. Traditionally, the user of a financial market model can apprehend the basic knowledge conveyed by that model, but cannot explore incremental knowledge related to the true price and the true profit determination. The same limitation holds true for the designer who might wish to incorporate new knowledge gained from the real world financial market domain. Incorporating new knowledge is a developer task that might necessitate a re-design of the model depending on the scale of the new insight to be recorded.

Encoding finance domain knowledge in a software application is not straightforward. This is mainly due to the gap between the designer's mental model and the developer's understanding of this model.

The designer's knowledge of the financial market and of trading mech anisms grows over time with the introduction of new systems and shifts from old to new trading models. In the context of financial markets, knowledge acquisition and construction is a continuous ongoing process and cannot be limited in space and time.

Distributed interaction enables the designer, the developer, and the user to cultivate their understanding of the requirement engineering of an OFMM and its use in developing a finished financial market product. Practically this can be achieved by providing privileged access to an OFMM script residing at a server that connects three clients: the modeller, the designer, and the user. Sun (et al, 1999) identified three possible modes of distributed interaction in a requirement engineering task (subordinative[14], coordinative[15], and collaborative[16]) and favoured the collaborative for an EM approach. In a collaborative relationship, there is no possibility of relying entirely upon closed-world representation and preconceived patterns of interaction. The interaction amongst all market participants is a situated intelligent interaction that can only be planned in advance to a limited degree, and knowledge for understanding emerges on-the-fly. Distributed interaction between the programmer, designer, and user of an OFMM allows data about requirements to be collected from all participants, makes it possible to visualize and analyse activities from the viewpoints of different participants, and provides open-ended interaction.

Every participant in the above model has their own domain knowledge: the designer has a deep knowledge in the finance domain; the programmer has a deep technical knowledge; and the user has an insight in doing a specific task that needs computer support and benefits from the designer knowledge. What makes the collaborative distributed interaction between these three participants feasible in an EM approach is the real meaning attached to observables and their state as communicated via a definitive script between the participants at the different client workstations. A sample collaborative interaction during the requirements engineering phase of an OFMM would address sharing insight between the designer, programmer, and user about the determination of the true price of the security. This is illustrated in the following dtkeden script communication between the three clients via the server.

```
sendClient("programmer"," true_price =
               (informedbuyers_per_unit_oftime == rush_rate) ?
                true_price+ticksize:true_price;");
sendClient("user"," true_price is (3*bid - ask)/2;");
sendClient("designer"," true_price is 64;");
```

[14] A subordinative distributed interaction assumes that the users should be able to provide all the knowledge required by designers because only they know what they want.

[15] A coordinative distributed interaction stresses the importance of user participation in design and postulates responsibilities for all the participants.

[16] A collaborative distributed interaction is concerned with sharing understanding that is socially distributed. Collaborators engage with issues of subjectivity and objectivity associated with distributed cognition [Hut95a, Hut95b] and common knowledge [Cro94, EM87].

Exploiting distributed interaction makes the OFMM more realistic and obviates the need to automate the role of different participants (e.g by having an intelligent dealer agent[17], or an intelligent investor agent). Smith (1997) argues that any approach to supporting a social context should take group activity into account. As introduced in chapter 2, a financial market comprises a social network involving individuals, companies, and governments. In the context of financial trading, this social network can be captured in the following diagram.

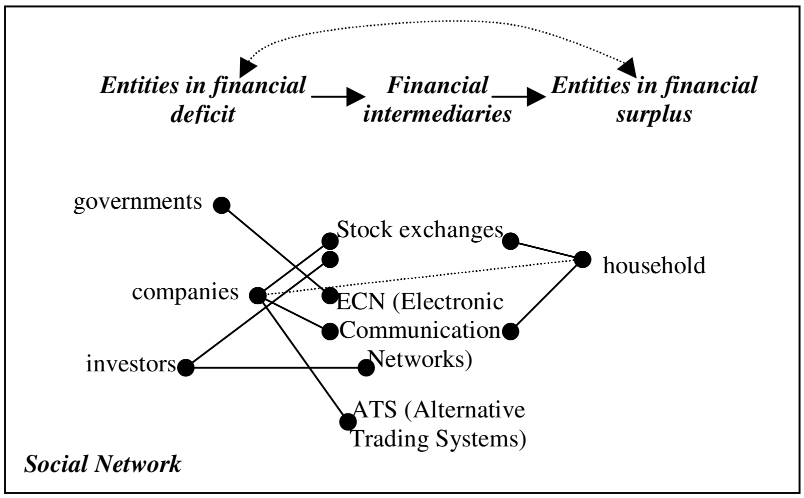


Figure 6.2 The social network in the financial market

Decision support is better targeted in a model where different human agents (buyers, sellers, and dealer) retain their identity and partake in their normal role as an agent within a distributed computing environment. This preserves the insight of each human agent into what action and judgement to take, while avoiding problematic issues associated with automating people.

A distributed model of the monopoly dealer simulation supporting the decision making of the dealer and of the investor would be more appropriate.

---

[17] This use of the term *agent* refers to a software component capable of autonomous actions. It differs from the use of the term agent in the EM literature, where it refers to an initiator of state change.

Claim 6: By adopting EM principles for developing an OFMM we can potentially have:

- a progressive computer-based support for the transition from the old to the new trading model;
- computer-based decision support for market participants;
- a closer integration between the software system development and financial trading related activities.

Supporting this claim by practical proofs is difficult in an academic research exercise conducted without industrial contact. It is helpful to review existing financial market models so as to get a better idea of what an OFMM can be and to choose a model that can be developed as a proof-of-concept for an OFMM. Such a proof-of-concept model can serve as a seed for more sophisticated OFMMs of the kind discussed earlier in this section.

6.3 The OFMM: technical implementation and practical applications

The technical implementation of an OFMM confronts the key issues associated with the shift from the old to the new trading model. These include:

- The experiential dimension of the computer-based software system development activity
- The openness, situatedness and evolutionary software system development activity
- The development of a computer-based artefact of subtle and dynamic nature capable of establishing a semantic relationship between the computer-based and real world activity
- The need to embrace emerging computer-based technologies (e.g. Virtual Reality, Web, multimedia, etc..)

6.3.1 The case study

The case study considered in this chapter draws upon several models for educational, analytical, decision making, and operational purposes that have been developed at academic and practitioner levels. These include:

The Wall Street Trader: The Wall Street trader is a wimp based application game with multimedia support, to help learning about the global financial community. The game has a simulated financial database covering two years of trading history. The user, the player of the game, is the investor and he/she can buy and sell stocks and read about a company's history. Some tools are available to the investor: an analyst (to help the user understand the news), an insider (to help the user uncover hard to find facts), and a spy (to see what other investors are up to). The game has a tutorial. The news database is fictional though inspired by real events. Each time the game is restarted the events are changing so that the game can be played many times without being repetitive.

Web-Based Trading Model: Boutell (1996) developed a web trading model using CGI (Common Gateway Interface) implementing a stock market trading system. As in online trading systems, the main features of this web-based model are to allow users (investors) to perform three tasks: 1) examine their portfolio; 2) buy and sell stocks; and 3) track the performance of stocks over time.

The Monopoly Dealer Simulation: This command line application simulates trading in a dealer market in which there is only one dealer (the user of the simulation model). The user's task (the sole dealer) is to set and adjust bid and ask quotes (raise, lower quotes, or narrow and widen the spread) to maximize his trading profits. The dealer (user) should know how to attract traders by adjusting his bid/ask quotes and spread. When the quoted bid/ask spread is wide, few uninformed traders will trade. To encourage uninformed traders to trade the spread should be narrowed. If the true security value is above the ask quotes, informed traders will buy from the dealer. They will sell to the dealer if the true security value is below his bid. Informed traders will trade more often and they will make larger trades when the dealer quotes are far from the true security value. The following diagram is relevant in depicting the buy/sell reaction of the informed investor according to bid/ask and true price value.

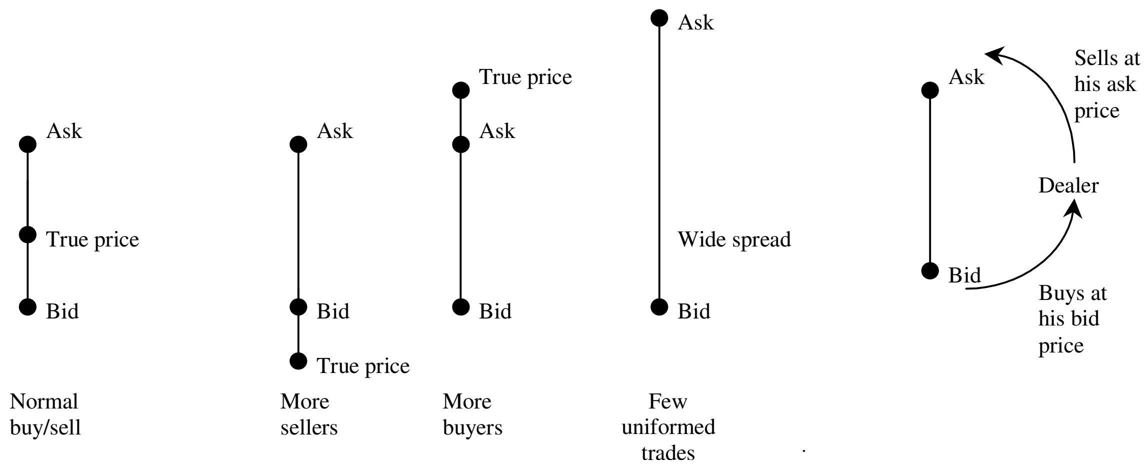


Figure 6.3 Investor's behaviour in response to dealer quotes

Head Trader: Head Trader[18] is a web-based educational simulation developed by the Nasdaq Stock Market®. It is based on an original model and software developed by two academics in the field of trading mechanisms - Robert A. Schwartz and Bruce W. Weber[19]. Head Trader simulates the experience of a Nasdaq Market Maker buying and selling stocks in a screen-based market environment.

Stock track: STOCK-TRAK[20] is an investment simulation, offering its users the opportunity to gain practical experience trading a wide range of investment vehicles.
(4i) System: the Integrated Investment Intermediary Information System (4i) developed by Consort securities systems Ltd.[21]. The system offers integrated investment management and stockbroking services. The system is WIMP based, with a GUI front-end and an SQL-Server relational database back end.

Konana et al (1999) model: In an attempt to model and analyse the effect of structural change in financial markets (the impact of online investment on the efficiency[22] of financial markets and the trading system in the short and long term horizon), Konana et al (1999)

[18] http://www.academic.nasdaq.com/headtrader/
[19] at the Zicklin School of Business at Baruch College, The City University of New York
[20] www.stocktrak.com.
[21] http://www.consort.co.uk
[22] 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

developed models describing the investor choice process and the revenue flow and incurred cost in online trading are presented. The models are represented in a static diagram illustrating the workflow of a financial transaction.

The choice of a particular model as a basis for developing an OFMM should take into consideration important aspects in each of the financial market models / applications overviewed above. Our aspirations for the model to be developed are to convey important issues raised in finance in relation to studies in market efficiency, the determination of the true price of a security, the transaction cost, the determination of the bid ask spread, the impact of the behaviour of different agents in the financial market (investors, dealers, ..) on market performance and operation. The emphasis in this model will not only be on the represented knowledge but on how that knowledge is experientially constructed and conveyed to the user. Each of the financial market models reviewed above conveys basic knowledge about the financial market in some way. The Wall Street Trader, through its enhanced multimedia support, provides an entertaining tutorial on buying and selling stocks and analysing the market based on a limited database of financial indicators and news. The web-based application of Boutell (1996), gives some idea of the main features of an online trading environment, but does not tackle any fundamental financial issue. It is a good model from which to study the technical aspects of building online web trading environments. The model suggested by Konana et al (1999) for transaction cost in an online trading environment is quite inspiring, but cannot serve as a starting point for a computer case study. Models developed by practitioners are important and admit further development, but industry support is needed to get the model approved by different stock exchanges at an international level.
The author has chosen a simple model similar in spirit to Harris's simulation and the Nasdaq Head Trader as a basis for developing an OFMM that addresses various financial market issues and involves complex situations and cases. Our basic seed model considers a market where a single security is traded and the dealer adjusts his quote to attract various types of buyer and seller.

6.3.2 The OFMM: A proof-of-concept

Two models were developed as a proof-of-concept of the practical use and technical implementation of an OFMM: using EM technology, and using virtual reality technology.

---

by investors, and the real efficiency of the transactions and the patterns of information flows beyond the interface.

6.3.2.1 Model developed using EM technology

As introduced in chapter 3, the principles of the Empirical Modelling approach are based on the concepts of observation, agency and dependency. The initial analysis of a domain to be modelled is made by identifying *observables* considered relevant by the modeller. These observables are grouped around the *agents* regarded as sources of change in those observables. The *dependencies* between observables are expressed in *definitions*. A set of definitions – a definitive *script* – corresponds to a single *state* of the model. Any particular state of the model should directly correspond to a possible state of its *external* referent. All these identifications (observables, dependencies, and agents) are provisional and subjective: they represent the viewpoint of the modeller. The *techniques* of the EM approach involve an analysis that is concerned with explaining a situation with reference to agency and dependency, and the construction of a complementary computer artefact – an *interactive situation model (ISM)* – that metaphorically represents the agency and dependency identified in this process of construing. There is no preconceived systematic process that is followed in analyzing and constructing an associated ISM. The modelling activity is open-ended in character. The LSD notation is used to classify observables and dependency in agent interaction.

The construction of the ISM for the chosen model involves an agent oriented analysis where the following observables are recorded:

- dealer (bid, ask, spread, inventory, true profit, actual profit)
- buyer/seller (informed / uninformed, quantity bought/sold, transaction price)
- simulation clock (simulation time and speed)
- transaction details (side, quantity, actual price, true price)
- security type
- market (monopoly dealer market, single security)
- warning messages to dealer

Observables are grouped around *agents* that are regarded as sources of change to those observables. Observables associated with agents are classified as oracles, handles, and derivates. An LSD template for the dealer agent takes the following form:

```
Agent Dealer {
State
    inventory, bid , ask , spread, actual profit, buyers/sellers flow,
    current status and history of transactions, time clock, his estimated
    true value of the security
Oracles
    flow of orders, order side (buy/sell), order quantity, inventory level,
    actual profit, his estimated true value of security, his knowledge of
    trader type (informed/uninformed)
Handles
       Bid, ask, spread
Protocols
    if (estimated true price > ask) || (informed trader rush to buy) ) →
    raise ask
    if (estimated true price < bid) || (informed trader rush to sell)) →
    raise bid
    if (spread is wide)|| (few uninformed traders are trading) → narrow the
    spread
    if (inventory is approaching the limit of +/-10,000 ) → adjust quotes to
    attract buy and sell orders appropriately
}
```

The ISM of the considered model is developed using the client server architecture of dtkeden (cf. Figure 6.4). The server provides a global market view including the knowledge hidden from market participants (such as the true price, the true position of the dealer, the type of an investor – informed/uninformed), as well as the publicly known information such as the dealer bid/ask/spread quotes, the current status and history of transactions. The client provides a dealer's view that includes the observables that the dealer can view (oracles), such as his position (actual profit and inventory level), the flow of buyers and sellers, and the current status and history of transactions. The dealer's actions (raising/lowering quotes) are also undertaken via the dealer's view and the results of these actions are transmitted to the server. Agents in the model are the dealer, the investor (buyer/seller), and the clock.

Many issues surrounding the trading behaviour of buyers and sellers and the strategic decisions of a dealer (the true price of the security; the role of the dealer in the determination of the true price, and transaction price; the type of investor (informed/uninformed); the buyer/seller and transaction flows; and the hidden intentions of the investors to buy or sell) motivate the thinking of different construals, each reflecting a particular scenario, to account for our weakly structured knowledge of the complex trading system. For instance, it might be that the true price is determined by the trading pattern, or that it is influenced in a non-deterministic manner by external events. Rules to govern the interaction are imposed to reflect each possible explanation of the state of observables.

Different construals may enable the exploration of issues concerned with market efficiency[23], trading behaviour, timing considerations, and transparency. Rules are imposed to govern the interaction with the construals and to reflect one possible explanation of the state of observables. For example, in the construal reflecting a trading behaviour, we impose a rule on the interaction with the model stating that the trading behaviour (buyer/seller flow) responds to dealer quotes and to the value of these quotes relative to the true price (cf table 6.1). This assumes that the trading pattern is totally under the control of the dealer when the true price is fixed and that informed investors are trading. Market efficiency is a more advanced concept in financial analysis and is yet more complicated to construe in a computer-based artefact. It can be explored by imposing rules about how long a trading pattern takes to affect true price, and consequently dealer actions and vice versa. Time is also an important factor in governing trading patterns and dealer actions, as there may be a delay before trading intentions materialize into trading actions. Market transparency is also an important concern: a simple interpretation to transparency would involve making the true price visible to all trading agents including the dealer. The construals should also take into consideration the conflict of interest faced by a dealer when aiming at maintaining an ordered market flow and making high profit.

Trading behavioural impact
Dealer actions ⎝ Trading patterns
External events ⎝ True price ⎝ Trading patterns
Trading patterns ⎝ dealer actions ⎝ trading patterns
Trading patterns ⎝ dealer actions ⎝ true price ⎝ trading patterns
Market efficiency impact
Dealer actions ⎝ trading patterns ⎝ true price
Dealer action & external events ⎝ trading patterns ⎝ true price
Time duration impact
Duration for trading intention to materialize in actual trading action ⎝ true price ⎝ dealer actions
Market transparency impact
True price is transparent to dealer ⎝ (true price ⎝ dealer behaviour)
True price is transparent to trader ⎝ (true price ⎝ trading behaviour)
note: the sign ⎝ means indicates a direct impact on

Table 6.1 Different construals in the case study

[23] This refers to efficiency as described in the efficient market hypothesis (EMH).

In modelling state in the financial market and the complexity of the trading activity an ISM is a rich computer-based artefact that can capture our evolving knowledge of traders' behaviour in terms of various observables representing:

- The probabilities of buying and selling,
- The potential time of delay for decision-making of buyers and sellers,
- parameters to determine density of trade
- how many buyers and sellers there are around
- how long are buyers and sellers prepared to wait
- how much buyers and sellers are influenced by the spread
- how the behaviour of buyer and sellers is correlated to true price

The model can include parameters and potential dependencies to support the rich construals reflecting behaviour of traders and the complexity of the trading activity. The state of the observables in the model can be changed through new definitions and re-definitions.

The ISM helps in exploring experientially fundamental and subtle issues related to the true price of a security and its essential elusive nature and relationship to the trading patterns and trader agency. 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 in various ways:

- as that value about which a dealer can most profitably pitch their bid and ask prices so as to maximise trading throughput
- as influenced by supply and demand
- as expressed through responses of buyers and sellers to the situation
- as influenced by the roles of informed and uninformed buyers
- as sensitive to potential dealer' s influence and their motivation for being able to "estimate true price"
- as sensitive to external factors beyond the control of buyers and sellers

Modelling true price in a tkeden model in principle allows us to exploit two powerful features: (1) construals that can be manipulated interactively and dynamically; and (2) dramatisation of the roles of many independent agents.

The ISM for a financial trading context could be adapted to a sale shop context. Different scenarios that arise in a sale shop can be considered where the dealer can gauge the level of interest of buyers. An 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.

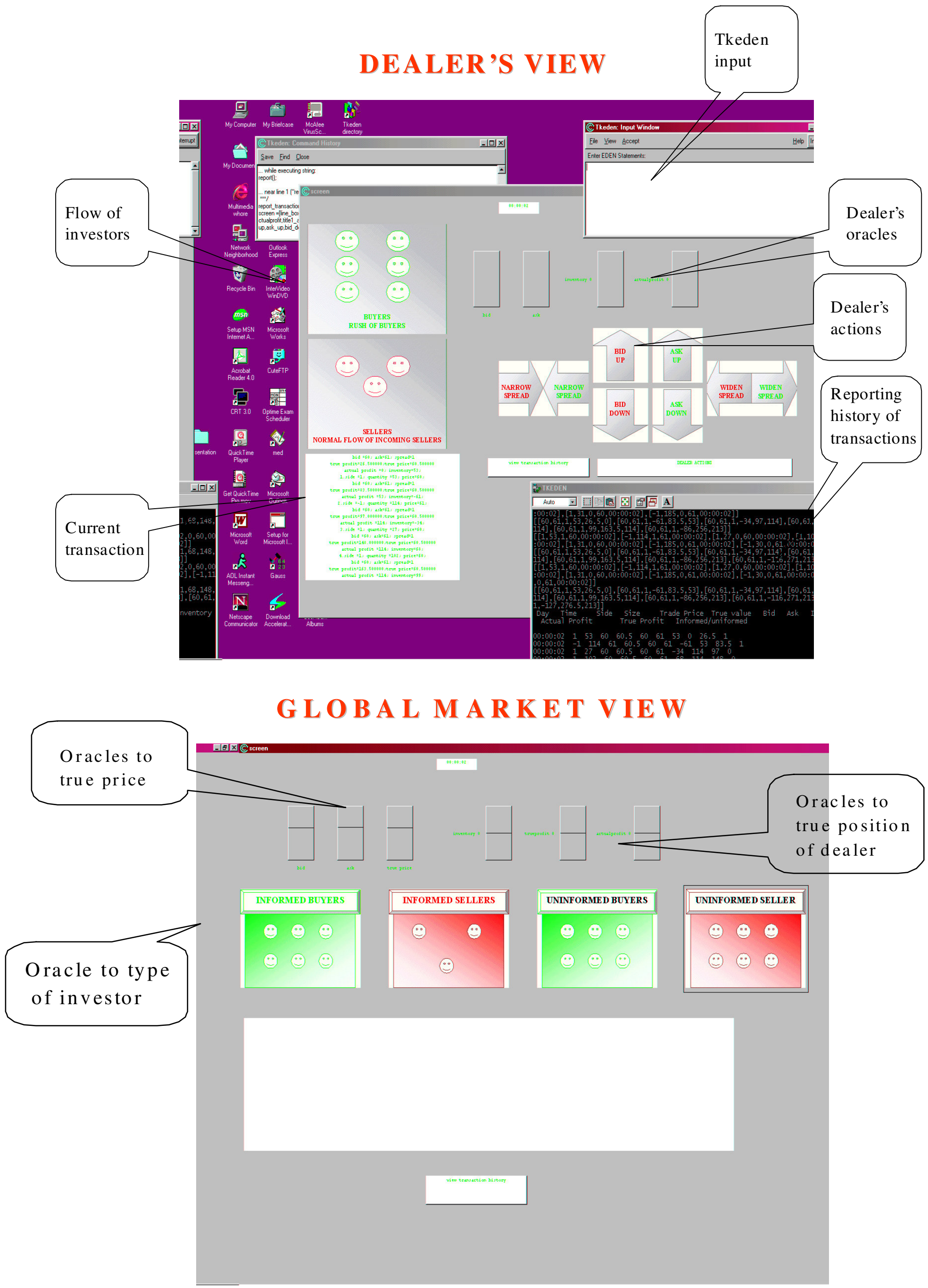
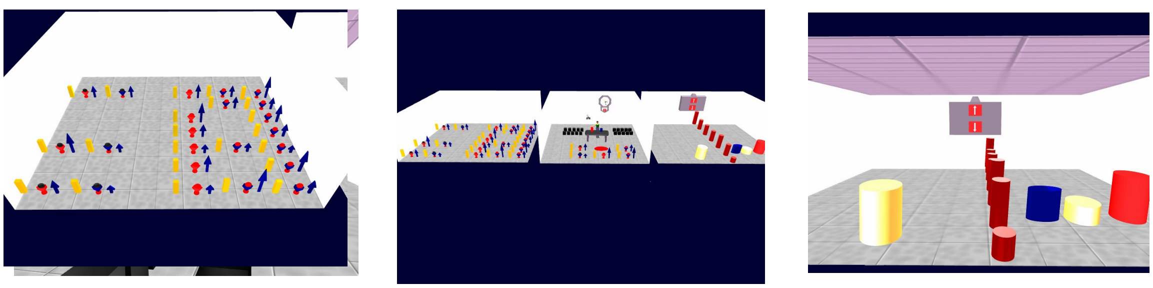


Figure 6.4 the distributed monopoly dealer simulation

6.3.2.2 Model developed using VR technology

The EM model for the considered case study can serve two purposes: as an artefact in its own right, and as a requirements model. In constructing a VR scene for the case study, the EM model serves as the requirements analysis. As an additional exercise, we have to find an appropriate visualization for abstract numeric indicators, agent actions, and the human (user) role in the scene, and to add sound support to produce warning messages to the dealer. The VR scene includes 3 rooms: the dealer action room, the transactions history room, and the hidden knowledge room. Transactions are saved in a file and are visualized in the transaction history room. The set up for the experiment is developed on a Silicon Graphics Machine running Irix6.5, using Parametric Technology Corporation's VR modelling tool Dvise, and the peripherals includes a 3D mouse as an input device, CrystalEYES glasses for the Stereographic image and 3D auditory feedback. Figure 6.5 shows snapshots of the VR scene.



Dealer Actions View *VR Scene of the Monopoly Dealer* *Transaction History View*

Figure 6.5 The VR scene

There is a very significant distinction between VR modelling for areas such as robotics as represented in papers such as [GC00], and its application to Virtual Trading. Whilst we can reasonably speak of "using VR to model the reality of a manufacturing assembly process", the reality of the virtual trading environment is an altogether more elusive concept. Where manufacturing assembly deals with objects and actions whose objectivity and real-world authenticity is uncontroversial, virtual trading is a prime example of an activity in which the impact of technology upon human cognition is prominent, and the character of its agencies and observables is accordingly hard to capture in objective terms.

The challenges faced in the use of VR for constructing virtual environments for financial trading are best revealed by drawing a comparison with its use in computer-aided assembly [GC00]. This comparison reveals a difference in the objective, considerations, approaches, and user role in constructing VR scenes for different contexts.

- The main objective in using VR for virtual trading is enhanced cognition of financial market phenomena; in the case of virtual assembly the main objective is to minimise the need for building physical prototypes.
- The issues to be considered in applying VR in financial markets and in virtual assembly differ in nature and importance. In virtual assembly, the major concerns are proper 3D picture capturing, conversion, and adding behaviour to objects; in VR for financial trading, they are geometric abstraction of financial concepts, integration with financial database, and distributed interaction.
- The steps followed to create a VR scene for virtual assembly and for financial markets are different. A linear, preconceived, set of processes can be followed to develop a VR scene for virtual assembly. These can be framed in three stages: defining objects to be assembled, preparing the assembly geometry for visualisation, and adding behaviour to visualised objects. Creating a VR scene for a financial trading context is more complicated and cannot be framed adequately in a pre-conceived way. However, a broad outline can be traced to guide the VR construction process. This involves: identifying entities (both those that admit geometric abstraction and those that have already a well recognised geometric representation) to be included in the VR scene; choosing an appropriate geometric representation for these entities; adding a situated behaviour and visualisation to entities; identifying the external resources (such as databases, files, data feeds, etc.) to be interfaced to the VR scene; and framing the role of the user intervention in the simulation.
- Where human intervention is concerned, the user's role in the VR scene is more open-ended in a financial context than in an assembly context. In a VR scene for assembly the immersion of the user is very important. Armed with helmet, gloves, and three-dimensional pointing device (such as 3D mouse and keyboard), the user can manipulate virtual objects with his hands. The user's hands, guided by the user's brain, interact directly with virtual objects. This makes virtual reality environments more appropriate for the assembly task than any alternative technology. Construing financial market phenomena is a function performed by the human brain. The mental model of the designer can be abstracted in a static diagram, a 2D computer artefact, or a VR scene. Geometric objects in the virtual scene might admit no counterpart in the real world - they are purely geometric metaphors. This makes a virtual scene just one of several possible representations. It also motivates a prior situated analysis exploring possible construals pertaining to the social context.

The above comparison highlights the need to support VR technology with principles and techniques to analyse and construe social contexts and to adopt appropriate visualisations for abstract entities (such as financial indicators) that have no real geometric counterpart. Current technologies for Empirical Modelling can help in construing financial situations and in representing state and the analysis of agency in state change, whilst VR offers enhanced visualisation and scope for user immersion and experience of state.

A VR scene can help in exploring a particular state in a social context. In developing the VR scene of the considered case study, the following conclusions were drawn:

- The pre-construction phase for a VR scene can benefit greatly from concepts drawn from the Empirical Modelling literature such as modelling state, state change, and the initiators of state change.
- VR technology needs to be better adapted for the representation of multiple agents acting to change the state and corresponding visualisation in a VR scene.
- The successful application of VR technology in modelling a social and data intensive environment will rely upon integrating VR with other programming paradigms such as databases and definitive programming.

6.4 Towards a Broad Foundation of Computing: a proposed EM – VR Merge

The VR model of the financial market, considered in this chapter, motivates the proposal of an EM-VR merge to empower VR technology with basic principles and techniques for modelling social contexts. This contributes to a broad foundation of computing based on EM and aiming at merging, where possible, disparate technologies.

Maad et al (2000) investigated the applications and prospects of VR technology in supporting the development of virtual environments for financial trading. The research suggests future prospects for VR technology in developing virtual environments for financial trading when integrated with other technologies such as database, and EM technology. A new perspective on the design, application and use of VR technology in modelling a social context, such as the financial trading one, is motivated. This takes into account the central human role, the need for appropriate geometric abstractions of concepts and real entities, the large amount of corresponding data, and the identification of actions and behaviour associated with virtual objects.

Further interdisciplinary research in the areas of financial market microstructure, electronic financial trading, Virtual Reality technology, database technology, business process modelling, interface design, and Human Computer Interaction is to be undertaken. The aim is to identify the role and uses of VR technology in developing virtual environments for financial trading and the adoption of appropriate performance metrics to assess its added value[24]. This involves the exploration of the use of VR technology in modelling the financial trading process, supporting the financial decision making activity, and designing interfaces for virtual environments for financial trading.

6.5 Summary and future outlook

Modelling financial markets is a broad and ambitious objective. Financial markets are facing major structural changes due to increased competition and the rising demand and need for cross-border trading. There is a rising need for better models to depict the reality of financial markets, and to explore the shift from the old to the new trading model. Interaction in a trading environment is particularly subtle and complex because it combines real-world knowledge and observation with real-time interpretation of abstract numerical data and indicators. Traditional mathematical models are not sufficient for such applications, where human behaviour is of paramount importance.

Modelling the impact on financial market structures of the introduction of new technical trading systems in general, and online trading in particular, needs more than traditional econometric approaches that operate on past transactions data. The ability to forecast the impact of a new technology or structural change prior to its introduction, and to investigate an optimal financial market structure and organization needs more than traditional financial modelling techniques and calls for cognitive and experience based modelling.

In assessing the prospect of EM technology in modelling financial market, an Open Financial Market Model is proposed. The theoretical and practical framework for developing the OFMM relies on EM principles and foundations. An OFMM differs from a program or a finished software product in its degree of openness, in its customisation for use by academics

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

and practitioners, and in its representation of the real financial market domain. A brief summary of the key characteristics of an OFMM follows:

- An OFMM aims at exploring the new trading model
- By adopting an EM approach, an OFMM serves as a support for situated knowledge construction of key concepts in the financial market such as trading cost, the determination of the true price of a security, price movement, and behaviour of market participants.
- The use of EM technology in an OFMM supports semi-automated decision making
- Distributed interaction features in EM technology enable user, developer, designer collaboration in the development of an OFMM.
- Distributed interaction involving market participants (broker, dealer, investment, trading systems) in an OFMM supports the exploration of a trading process model and strategic decision support to market participants.

EM proposes basic principles for software system development in the financial market context and supports the claim in [Sun99] that software system development is a context dependent activity that cannot be detached from its real world context and cannot be abstracted in formal methodologies and rigid development cycles.