REALISING VIRTUAL TRADING: WHAT PRICE VIRTUAL REALITY?

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ABSTRACT
Computerisation is about to overtake markets that traditionally depended on physical presence to bring buyers and sellers together in one place. Providing appropriate interfaces for trading environments is a challenging task. In the context of financial trading, the behaviour of different trading parties (investors, brokers and dealers), trading signals, economic and financial indicators, and trading systems, constitutes a complex environment which is difficult to capture in a mathematical model, a computer simulation, or a textual description. This paper discusses the prospects for developing new environments for Virtual Trading that combine VR modelling with a new approach to computer-based modelling that has been developed at the University of Warwick [1].

1. INTRODUCTION

Traditional stock exchanges are witnessing major structural changes due to increased competition from alternative trading systems and Electronic Communication Networks and rising investors' demand and financing needs. These structural changes are manifested in the introduction of new trading systems (such as screen based trading), the extension of trading duration, and the opening of new trading channels. The old trading model adopted by traditional exchanges is no longer adequate and new trading models are being introduced, revolutionising old execution, clearing and settlement processes. These developments impact on the behaviour of all market participants (investors, brokers, dealers, and market makers) and are reshaping the financial market microstructure [3] in terms of transaction cost, bid-ask spread, price volatility, trading volume, information effect, and best execution price. The decision process and dealing strategies of market makers are changing, the role of the broker is questioned, and the investor is adopting new trading strategies to boost his profit and gain deeper knowledge of the financial market.

Exploring an ideal trading system minimizing transaction cost and increasing market efficiency is a major concern in the area of financial market microstructure. 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. Virtual Reality [4], with its orientation towards immersing the human actor in a computer-generated environment, is potentially much better suited to modelling state where human activity is central. VR's capacity to handle objects and their properties, to allow user immersion, and to emulate observation of the real-world using a 3D graphical display, make it an obvious candidate for application in this field.

This paper proposes new principles for the development of environments for virtual trading to deliver VR using an approach to computer-based modelling known as Empirical Modelling (EM). First, the paper overviews EM and VR and their role in constructing environments for virtual financial trading. The paper then discusses the challenges of adopting VR technology to model complicated social environments (such as virtual trading) and proposes the merging of the conceptual framework of the Empirical Modelling approach with the VR design and construction. Second, the paper considers a case study of the Monopoly dealer textual simulation developed by L. Harris [2]. A 2D simulation and a VR scene are constructed and compared with the initial text based simulation. The paper concludes with our findings about the use of VR for modelling a social context such as virtual financial trading.

2. VIRTUAL ENVIRONMENTS FOR FINANCIAL TRADING: THE VR AND EM VISION

2.1 About EM

Empirical Modelling (EM) is a new approach to computer-based modelling that has been developed at the University of Warwick. The Empirical Modelling framework provides a set of principles, techniques, notations, and tools. *Empirical Modelling principles* are based upon *observation, agency, and dependency.* By adopting these principles, EM attempts to represent and analyse systems in a way that can address the complexity of the interaction between programmable components and human agents. The central concepts behind EM are definitive (definition-based) representations of state, and agent-oriented analysis and representation of state-transitions. *Empirical Modelling techniques* involves 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 analysing and constructing an associated ISM. The modelling activity is open-ended in character, and an ISM typically has a provisional quality that is characteristic of a current - and in general partial and incomplete - explanation of a situation. The special-purpose notation LSD has been introduced to describe agency and dependency between observables. An *LSD account* is a classification of observables from the perspective of an observer, 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*); those indivisible relationships between observables that are characteristic of the interface between the agent and its environment (its *derivates*); and what privileges an agent has for state-changing action (its *protocol*). The tkeden interpreter is the principal *modelling tool* that has so far been developed: it supports definitive scripts for line drawing and window layout and allows the user to establish dependency relationship between scalars, list and strings using built-in user-defined functions. Dtkeden is a distributed version of tkeden: it allows several modellers to co-operate through communicating definitions and actions within a client-server configuration of tkeden interpreters.

Empirical Modelling emphasizes modelling states and the role of agency in changing state. Agent actions initiate state change. A state is represented in a script of definitions linking observables through dependencies. Agent actions are modelled by redefinitions. In constructing environments for virtual financial trading, 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.

2.2 About VR

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

Current use of VR is limited to the exploration of a real physical object (e.g. car, cube, molecule, etc..) or a physical location (e.g. shop, theatre, house, forest, etc..). In the course of exploration the user is immersed in the VR scene, and can walkthrough or fly through the scene. The user's body and mind integrate with this scene. This frees the intuition, curiosity and intelligence of the user in exploring the state of the scene. In a real context, agents intervene to change the state of current objects/situations (e.g. heat acts as an agent in expanding metallic objects, a dealer acts as an agent in changing bid/ask quotes and so affects the flow of buyers and sellers). Introducing agency into a VR scene demands abstractions to distinguish user and non-user actions especially when these go beyond simple manipulation of objects by the user hand, or walking through and flying physical locations.

2.3 The motivation for integrating EM with VR

The challenges faced by 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 [Gar]. 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 markets 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 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.

3. CASE STUDY: THE MONOPOLY DEALER SIMULATION

3.1 Description of the case study

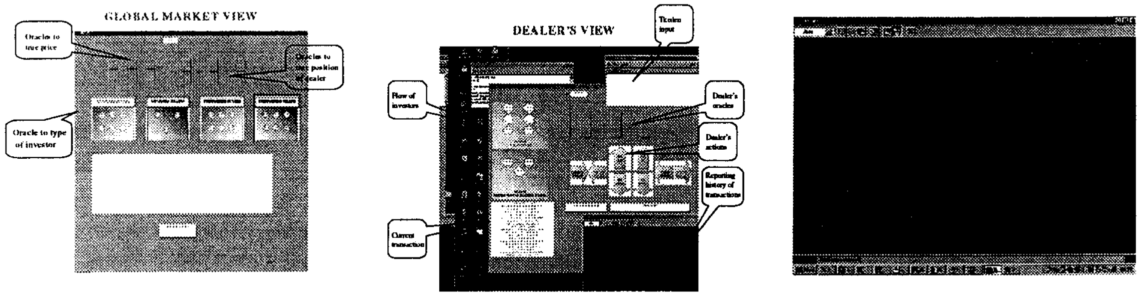
Harris's Monopoly Dealer (see [2] for more details) simulates trading in a dealer market in which there is only one dealer (the user of the simulation model). The user's task (the sole dealer) is to set and adjust bid and ask quotes (raise, lower quotes, or narrow and widen the spread) to maximize his trading profits. The computer model simulates traders arriving at random times to trade with the dealer (user) at his quoted prices. The aim of the simulation is to raise the awareness of its user (playing the role of a dealer) to the trading behavior of different types of investors (informed/uniformed), and the true value of the security (changing through time and known to informed traders).

3.2 From textual to 2D and VR simulation: the evolving state visibility and state exploration

The Monopoly Dealer is a closed world simulation of a simplified market where there is only one dealer, one share, buyers and sellers, and a time clock. This distances the simulation from reality and limits its scope to convey the true experience of a typical dealer. The simulation uses abstract representations for the buy/sell orders flow, true price, type of investor (informed/uninformed); keyboard press for dealer (user) actions; and mathematical computation of true/realised profit. Simulation results and transaction history are represented by tables. Textual representations are used to display the simulation time, current state, dealer's actions, and warning messages to the dealer.

Many issues surrounding the trading behaviour of buyers and sellers and the strategic decisions of a dealer are abstractly represented in the simulation by a random generation of key variables whose mathematical formulation cannot be determined. These include: 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. This prompts us to think 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.

A 2D version of the original textual simulation was developed using the client server architecture of **dtkeden**. 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/uniformed), as well as the publicly known



2D simulation (Market View) *2D simulation (Dealer View)* *Original Textual Simulation*

Figure 1. The 2D and textual simulation

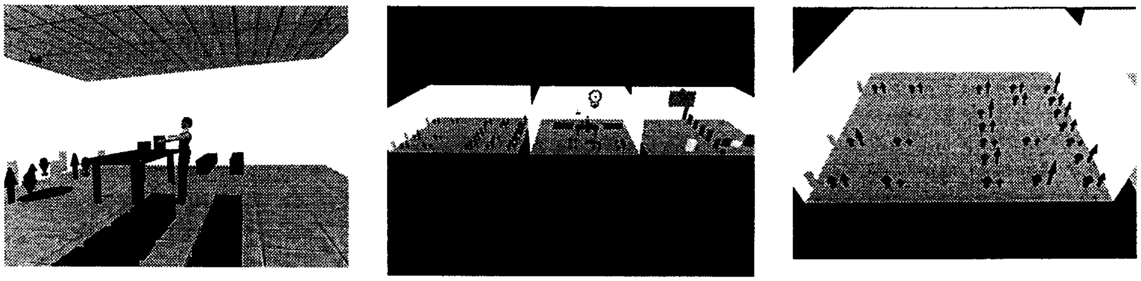
information such as the dealer bid/ask/spread quotes, the current status and history of transactions. The client provides a dealer's view that includes the observables that the dealer can view (oracles), such as his position (actual profit and inventory level), the flow of buyers and sellers, and the 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 observables are associated with each agent and are classified as oracles, handles, and derivates. An LSD template for the dealer 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 state of the model is captured in a script of dependencies such as:

```
informedbuyers_per_time_unit is (true_price-ask)>0 ? rush_rate : normal_rate;
informedsellers_per_time_unit is (bid - true_price)>0? rush_rate : normal_rate;
uninformedbuyers_per_time_unit is (spread<=upperlimit_for_narrowspread)?rush_rate: normal_rate;
uninformedsellers_per_time_unit is (spread<=upperlimit_for_narrowspread)?rush_rate: normal_rate;
screen is(true_price- ask)>0? [buyers_flow, clock, current_transaction, dealer_actions,
dealer_position, dealer_quotes];
```

In constructing a VR scene for the monopoly dealer simulation, the EM analysis was imported. As an additional exercise, we had to find a proper 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 distributed views in the 2D simulation were replaced by a single VR scene including 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, and using Parametric Technology Corporation's VR modelling tool Dvise, and the peripheral includes a 3D mouse as an input device, CrystalEYES glasses for the Stereographic image and 3D auditory feedback. Figure 1 shows snapshots of the 2D client/server views, the original textual simulation, and the VR scene.



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

Figure 2. The VR scene

4. CONCLUSIONS

There is a very significant distinction between VR modelling for areas such as robotics (as represented in papers such as [17]), 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 character of its agencies and observables is accordingly hard to capture in objective terms. Empirical Modelling supplies an appropriate framework within which to address the ontological issues raised by such applications of VR [20]. Current research by Cartwright [x] is aimed at merging EM and VR in a web-based framework. The work carried out for this paper points to the following conclusions:

- A VR scene can help in exploring a particular state in a social context.
- 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 social and data intensive environment relies upon integrating VR with other programming paradigms such as databases and definitive programming.

We propose to apply quantitative and qualitative metrics to our case study to assess the potential benefits of VR in modelling a social context. The profitability of the dealer's position with reference to a particular scenario can be used as a quantitative metric to evaluate our three different simulations. Cognitive Dimensions [x] can be used to assess the qualitative aspects of the VR scene. Two dimensions are appropriate: the visibility and the viscosity.

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KEYWORDS
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