A SMART-SHOP SYSTEM - MULTI-AGENT SIMULATION SYSTEM FOR MONITORING RETAIL ACTIVITIES

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ABSTRACT
This paper outlines a concept of employing intelligent agents to simulate and deploy a Smart-Shop System for retail environments. The discussion will examine the technical and conceptual challenges, main ideas and the final design rationale. The design model of the Smart-Shop System uses Multi-Agent Simulation Systems (MASS) and distributed middleware frameworks to automate a wide variety of asset monitoring and control tasks in traditional and distributed system concerns, which can be applied to similar application areas. Retail organisations containing any form of physical inventory can benefit from the proposed software solution by allowing assets to be efficiently managed and monitored. This would improve the quality of business trade and strategic marketing to sustain sales growth.

Keywords: Information Technology, Intelligent Agents, Inventory Management, Retail Commerce, Software Engineering

1. INTRODUCTION
With the advances in ICT technology, modern inventory control methodologies employed in retail environments require manual verification by sales staff when performing periodic stock-takes. The hidden labour costs of inventory control, such as locating inaccessible items, returning misplaced items to their original locations and basic theft prevention tasks such as bag inspections can result in decreased human resource efficiency to assist the individual needs of customers.

The development of autonomous wireless sensors in the past decade, in terms of cost, performance and component size, has reached a stage where practical technological applications in retail facilities has become a feasible option in monitoring inventory. Meanwhile, the cost of labour continues to increase due to economic conditions, coupled with the training costs of hiring new sales staff, such as natural attrition, all add to the overall cost of providing customer rapport in retail environments (Buckland 2006). Therefore, inventory control tasks, such as stocktaking, resorting and theft prevention; increase proportionately with labour costs as the size of a retail store's inventory increases.

The implementation of software intelligent agents in simulating support service scenarios is an evolving software engineering concern. This research investigation is designed to model various concerns in retail environments to demonstrate the feasibility of using intelligent agents to assist asset management decisions in commercial organisations. By determining the essential requirements to build a framework which the simulation will operate, including retail space, inventory quantity and the headcount of customers and retail staff; the project aims to simulate the practical application of using wireless sensors in retail environments with the coupling of traditional monitoring systems such as closed-circuit television, entry gates and various check points.

The theoretical potential of wireless sensor networks (WSN) can be viewed beyond the traditional inventory control technology domain, such as bar-coding and RF security sensors (Blackwell 2003; Buckland 2006), as wireless technologies are not bound by line-of-sight constraints. The project aims to develop a practical implementation of a sensor network environment that can be simulated with software intelligent agents in the scope of a retail organisation.

2. EXAMINING INVENTORY SYSTEMS IN RETAIL ORGANISATIONS
The development of novel systems to meet the special needs of retail environments can be built around existing industry knowledge of sensor network technologies, and driven by scientific initiatives for Smart-Systems in retail organisations. The demand for the implementation and development of such systems cannot always be met by commercial software enterprises, so a considerable interest is needed to appoint local staff to manage and direct the effort. However, these staff would have limited experience in designing, coding, configuring, interfacing and installing traditional systems and would not have management experience. Thus an emphasis in training and modelling the simulation should be a priority in the final model, for retail operators to provide feedback as to the authenticity of the simulation model.

The fundamental concepts to be examined in realising the Smart-Shop System are as follows (Blackwell 2003; Buckland 2006):

- The 'Smart-Shop' refers to the store's automation of procedures. The topic scope is the context of a retail store with distinct, physical collections.
- Stock records can be data-intensive as inventory varies, as the store may need to store unique physical or component attributes of the inventory.
- Store records must be concerned with specific quantities of merchandise; a store that has inaccurate stock control will not function efficiently
- Each product record contains unique details of each item, including the quantity and item particulars, including serial numbers, brand, model number and price (both wholesale and mark-up values).

For these main concerns, the automation of record-keeping and asset management in a retail store reaffirm the need to ensure that records remain accurate and consistent. Furthermore, the automation of record-keeping with a perpetual inventory system allows the decentralised access to records. Retail staff and customers can verify the stock quantity and its location without being physically present through visual verification. The cost trends of technology and labour consistently show how computerised automation is most effective when tasks are tedious and monotonous in nature, as shown in Figure 1. Tasks such as physically locating merchandise on the shelf, and ensuring the correct sorting order, are typical examples of manual procedures accomplished in retail environments that are prone to error.

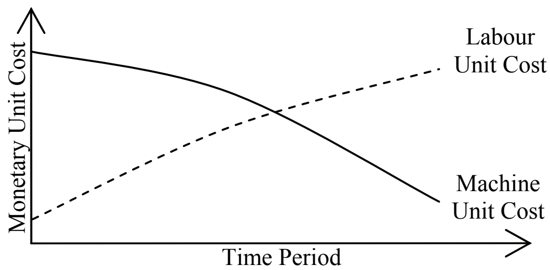

Figure 1: Labour and Technology Trends (Buckland 2006)

The common assumptions made in the context of modern technology to plan ahead for future concerns are listed below (IBM Corp. 2006; Blackwell 2003):

1. Computational Efficiency: Improved computing performance leads to lower cost of ownership. This increases the accessibility and maintainability of computer technology by the end-user.
2. Automated Inventory Monitoring: Wireless sensor network technologies will become more ubiquitous and deployable in confined or restricted spaces, leading to improved optimisation and deployment. Existing bar-coding technologies requires line of sight and require manual operation.
3. Data Storage Capacity: Storage costs expressed as per unit cost decrease as data capacities of storage mediums increase. Data access rates to storage mediums continue to improve over time.
4. Labour Optimisation: Labour costs continue to increase as a result of economic factors, principally with inflation. Manual and repetitive tasks are most prone to inaccuracy, which can lead to inefficiency.

Providing customer services in a typical retail store continues to be labour intensive, with up to two-thirds of a retail budget expenditure accounting for human resources. The purpose of simulating a Smart-Shop System is to demonstrate the feasibility of modelling a retail environment to examine real-world concerns through multi-agent systems. The project aims to gather and structure the simulated data through rudimentary data mining techniques to determine the information that is most suitable for aiding the business decisions of the retail organisation.

The practical implications for implementing the system will be based on the final project system implementation. The main focus is the feasibility of using the simulated data to convey the information to the business operators in such a fashion that would influence future planning decisions, as such optimising operational efficiencies that reducing capital tied up in inventory.

3. SMART-SHOP SYSTEM – THE SOLUTION CASE STUDY

The main concerns of the project are structured so that their content is not interdependent on one another, but are complimentary in nature, delivering a cohesive set of functionalities once completed. The component concerns are examined in detail (Jacobson 1998):

3.1. Review of Underlying Technologies

To examine hardware technologies used in the Smart-Shop System through wireless sensor networks. The nature of sensor networks lends itself to employ a distributed software middleware infrastructure that would interconnect the simulation logic and the data processing modules, thus forming the basis of the technical implementation of the system architecture.

3.2. The Development Methodology Employed

The Software Analysis and Design methodology examined in the scope of the project is based on the iterative development model. The basis for implementing the iterative model allows for the active participation of the business operators to review the modelling scenario, such as to fit with their operational concerns.

3.3. Development of a Software Prototype

The implementation of the system will ascertain the degree of interaction of business operators to make prudent business decisions for the needs of the retail facility. From the results of the prototype to generate relevant monitoring activity, an analysis will consider further research to improve the intelligence logic to suit the model of the simulation domain.

The needs of the retail organisation to make relevant decisions can affect the quality and marketability of inventory to potential customers. Retail employees need to recognise current marketing methodologies to improve underlying sales, by being in touch with customer needs. Records that are consistent with the buying patterns of inventory turnover are an important resource to understand the customer's buying preferences and the marketability of future stock.

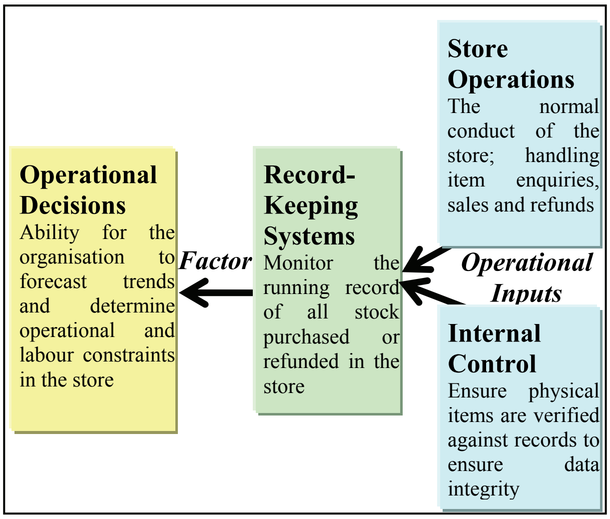

Figure 2: Operational Decision Chart (Blackwell 2003)

Computerised record-keeping systems are used in retail environments to obtain the necessary information to make operational decisions using the perpetual inventory accounting method. As shown in Figure 2, the record-keeping systems maintain a current record of the merchandise held by the store at any given time. This record is maintained by a computerised inquiry system, integrated into 'self-serve' kiosks or accessed by retail staff directly, to ensure that merchandise bought, replaced or refunded are accounted throughout the store's operation.

While computerised record-keeping management has modernised the process of retail transaction procedures, internal control is still necessary to ensure current inventory records of the store remain consistent. The annual or periodic stocktaking of a store is a core element of internal control to account for any discrepancies that may exist between the records and the physical merchandise held at any given time.

The context of the paper will examine the feasibility of using a multi-agent simulation to demonstrate the potential of improving internal control through the use of wireless sensor networks. Unlike traditional inventory control technologies such as bar-coding, wireless sensors with Radio Frequency Identification (RFID) technology can detect items that do not have to be read at line-of-sight. Thus, the manual process of stocktaking can be enhanced as long as the inventory is located within the proximity range of the wireless sensors.

4. DEVELOPMENT METHODOLOGY

The development of the Smart-Shop simulation system has been influenced in part by the industrial experience gained by the contributors of the paper, while permitting the ability for the contributors to reflect on the theoretical content of the material. The philosophy of all practice based engineering programs in University of Technology, Sydney (UTS) is reinforced with theory and industrial and commercial practice in the final year subjects Information & Communication Technology Analysis (ICTA) and Design (ICTD) (Chaczko et al 2006; Chaczko et al. 2004). The Australian Federal Government accredited program has been recognised as embodying world leading standards and practices, with educators all having held positions in industry as well as undertaking research programs; thus providing an additional academic quality process.

Out of the main design constraints when creating a new solution, foremost is that the system must be able to be completed and deployed within a predefined time. The constraint against an extensive prerequisite structure results in a limited number of core requirements, such that the basic technologies must be reviewed and assessed early in the development stage before important decisions are taken. The components of the software development processes are examined:

4.1. Software Technologies

The design of Smart-Shop System is based on the multi-agent simulation system by AnyLogic (Vangheluwe 2006). AnyLogic is a commercial application that generates the graphical agent-based models into Java code stubs. The code can be extended and customised for further development by importing the main libraries into a Java Development Environment such as Eclipse.

The main base object of the software agent forms the basis of which additional software agents are added together to suit the simulation model, which is made of Java objects instances in a vector array to achieve multi-agent capability. Interactivity between agents is achieved by establishing 'communication protocols' between agents, depending on the message content and information relayed, achieved by Remote Method

Invocation (RMI). State feedback and interactivity of the simulation environment is achieved through the 'root' object animating each instance of agent.

4.2. Software Quality Processes

Good quality assurance practice depends on the characteristic rules imposed upon the deliverables to ensure consistency and uniformity throughout the scope of the software development process (Barbacci 1996, Booch 1991).

- **Coding Structure:** Ensuring name conventions, the structure of each method and attribute declared, along with the file structure of the project remains consistent and modular.
- **Code Versioning:** Mechanisms to trace back software at all revision instances. This ensures that when the prototypes reach a level of stability, they will be branched off the development branch and backed up for archival purposes.
- **Document Versioning:** Versioning is implemented on all documentation produced, with the versioning rules based on incremental document revisions, according to minor/major document modification.

4.3. Software Analysis and Design

The formal analysis of the Smart-Shop System is categorised by the identification of major stakeholders in the system. This will assist in requirement analysis and ensure the completeness of software requirements.

The system is designed through an analysis into the stakeholders of the system and how they will interact with the simulation, of which to describe the environment of the Smart-Shop System within the scope of the users who will interact with the simulation. This will serve as a basis to involve the main stakeholders who will influence the final design implementation by encapsulating the system's composition and the interfaces for user interaction.

- **End-Users:** The business operators are the end users of the system. They will use and administer the software system for their modelling purposes, and as such there is an interest for the developers to ensure requirements fulfils their expectations.
- **Developers:** The contributors of this paper who are involved in the project and its maintenance. This includes the project manager to oversee project schedules, and the software engineers responsible for implementation.
- **Official Bodies:** Government and Retail bodies that supervise commercial practice standards and budgetary concerns. The stakeholder is in charge of enforcing legislation and/or organisational by-laws may affect the final product release.

4.4. Software Project Management

The concerns of the project quality, risk, and resources at each stage in the project lifecycle, are achieved by determining the software development process most suitable for the Smart-Shop System. This is examined through presenting the project results and artefacts.

The project was implemented according to a tailored prescription of the iterative development model. The rationale was the incremental nature of which the project was to be delivered. While the core elements of the project were complete, the project requirements had to be factored into the software implementation to satisfy the iterative prototyping philosophy in Figure 3.

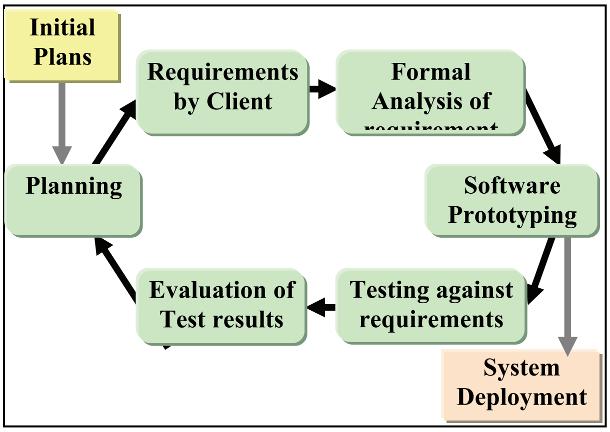

Figure 3: Iterative Development Model (Kruchten 1996)

An important factor throughout the development strategy was to consider the change in scope as the implementation came into fruition, and thus ensure that the core requirements of the project continued to be satisfied with the relevant stakeholders of the Smart-Shop System. The simulation functionality was included incrementally as the prototype was demonstrated with the end-users of the system.

4.5. Software Architecture and Middleware

The role of software architecture and the selection criteria for software architecture had to be considered when developing the system prototype. An emphasis on implementing open infrastructure concepts and middleware was a core quality attribute for the system to ensure portability, scalability and interoperability of the Smart-Shop System. The system's software architecture is based on a distributed architecture. A distributed architecture would allow simulation agents to call a remote object, as it would when invoking another local object; in addition each software module can be deployed on different processors to allow processing load across multiple workstations.

The middleware implementation is achieved through the Jini Middleware System (Chaczko 2005), as its fundamental design allows for network 'plug-and-play' capability. While Jini itself is written in Java, the clients and services can be written as a wrapper around non-Java objects. The Jini System, known as a 'Federation', is a suite of clients and services communicating via the Jini Protocol, which implements the Java Remote Method Invocation (RMI) mechanism.

5. EFFECTIVENESS OF THE CONCEPT

An agent-based approach to software system analysis, design, simulation and delivery has significant benefits to the developers and end-users. In addition to this there are economic advantages that benefit the business community. These advantages have many dimensions that may pertain to effective use of ICT technology in inventory management strategies (O'Brien 1991; Yang 2003):

- Strategic Advantages: A net commercial benefit from improved management and awareness of critical projects are applications that fail less often, either perceived or real. Organisations are often not rewarded directly through higher reliability, scalability, robustness, maintainability and usability, yet these are tangible economic consequences from utilising better solutions.
- Knowledge Advantages: Developers will disseminate their skills and methods through their professional and informal contacts, thus providing a multiplier effect of the experience to the user.
- Commercial Applications: There is a strong potential for adaptation of similar to Smart-Shop System to venture into commercial applications beyond the retail domain.

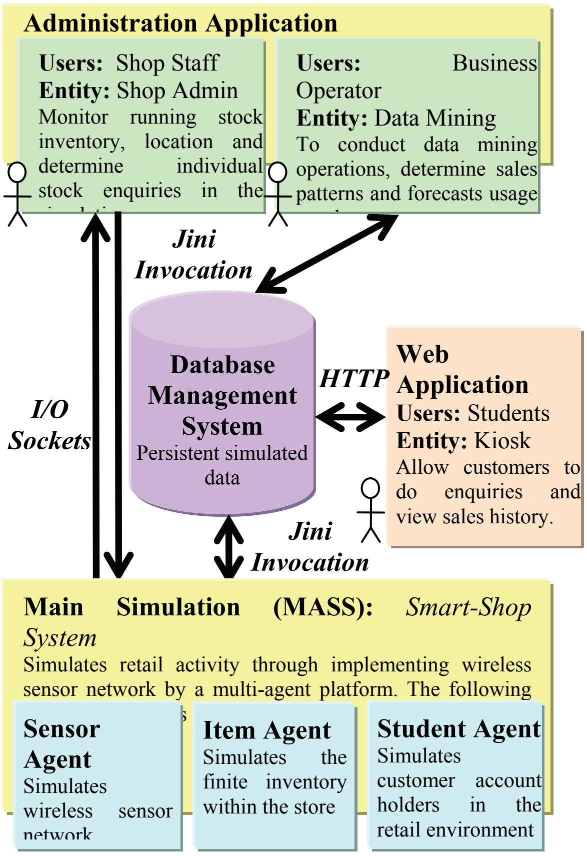

Figure 4: Smart-Shop System Architecture

As elaborated in Figure 4, the implementation comprises of a distributed architecture encompassing a multi-agent simulation that simulates the activity of a retail store that implements wireless sensors to track inventory. This simulation system will comprise of individual intelligent agents, including the store account holders, the merchandise and wireless sensors which will interact in a common shopping ground.

The design of the Smart-Shop System emphasises user customisation, in that scenarios are created to suit the unique layout of a store. Items can be placed at any given area, while pre-defined item attributes will affect the customer's behaviour and environment interactions, captured in visual depictions shown in Figure 5.

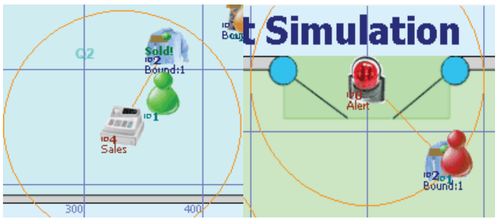

Figure 5: Simulated Sale and Attempted Theft by Agent

The Smart-Shop System in Figure 6 graphically displays transaction events, in which real-time activity including merchandise enquiries and stock-takes are handled by an administration application. Non real-time events, such as purchases or refunds and item tracking are saved to the database for data mining processes and store activity forecasting. Statistical graphs present the real-time state of the simulation in terms of quality of service, concerned with the wireless infrastructure's capability to handle transaction events in the store.

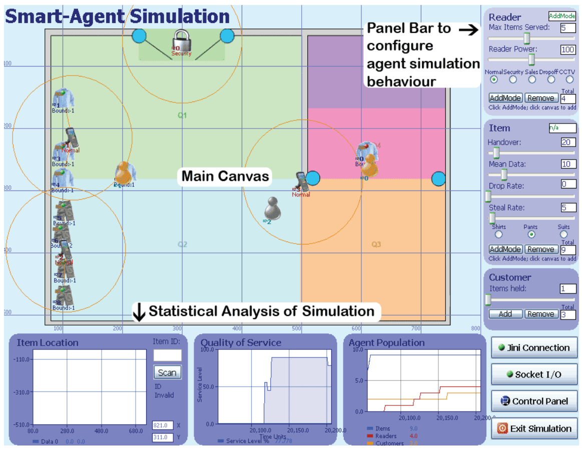

Figure 6: Smart-Shop System Application Screenshot

A preliminary run of the simulation to demonstrate the proof of concept is shown in Table 1 below. The simulation was run with the test case assumptions:

- Each individual scenario was run for approximately 2.4 hours, with the total test run elapsing after 12 hours.
- The simulation is constrained to 2 dimensions.

- The retail store area was made to 100m^2 to scale, split into 5 different rooms.
- 30 RFID readers were placed in an even order around the store, each with signal strength of 3m^2. This means that 90% of the store area is covered by the readers, with 10% non-signal coverage.
- 250 items affixed with tags will always be read the readers when they come into range, with environmental factors such as signal attenuation not factored into the simulation.
- 100 Customers are assumed to only have 4 distinct behaviours: to purchase items, steal items, acquire items for browsing, or return items.
- Items that are stolen will only be recorded by inventory. Aspects such as theft prevention through security guards and closed-circuit television are not factored into the simulation.
- Sales complete refers to total customer sales divided by total of all customers entering the store.
- Average Time Spent Shopping refers to the average time spent for each agent to browse for items
- Quality of Service refers to the percentage of number of inventory monitored compared to the total number of inventory in the store.

Table 1: Results from Test Case Proof-of-Concept

Scenario Micro-Perspective		Results: Macro-Perspectives		
Avg Item Value	Sales to Theft Ratio	Sales Completed	Average Time Spent	Quality of Service
$25	80:20	87.42%	5m 32s	72.15%
$50	70:30	73.81%	11m 12s	81.16%
$75	60:40	61.59%	15m 23s	85.71%
$100	50:50	49.82%	26m 3s	89.42%
$150	40:60	39.11%	31m 44s	88.91%

The simulation results can be interpreted according to the perspective of each user concern:

- Simulation micro-perspectives are of the concern of the test case executor. This involves collecting and entering statistical datasets of the retail environment to be modelled in the simulation. By setting the unique attribute of each stock, this will determine the customer's interaction with the stock.
- Simulation macro-perspectives deal with the concerns of the retail manager and decision makers. Quality of service data is highly significant to the end user, as the results will be interpreted to determine if a wireless sensor network setup is suitable, given their unique business scenarios.

The test scenarios results in Table 1 are only to be interpreted from a proof-of-concept perspective, given the artificial nature of the test constraints. The gathered results demonstrate that there is a potential basis for an improvement in the simulation model and input dataset, such that a more thorough analysis can be established to determine meaningful statistical trends.

6. CONCLUSION

The Smart-Shop System, through its design and implementation, achieves its principle objective of providing an accessible and effective software simulation for managing assets of retail organisations. By demonstrating the feasibility of implementing the system in an open distributed architecture with Jini, it accomplishes the integration of middleware infrastructure such that the end users can assess their inventory control strategies from a remote location.

A functional prototype of a retail environment is developed that incorporates wireless sensor network technology. The system simulates a generic sensor network system as an internal control mechanism, with the ability for end-users to examine their own circumstances for which sensor networks could improve their operational procedures. The use of statistical performance modelling allows the end user to quantify in real terms the benefits of using sensor network technology in a retail organisation. The simulated data can be examined through external data mining to plan placement strategies and forecast transaction trends.

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