# Intelligent Agents to Simulate Educational Environments - A Smart Library System

Zenon Chaczko[1], Christopher C. Chiu[2], Essam Rahali[3]

[1] Zenon Chaczko, ICT Group, Faculty of Engineering, University of Technology, Sydney, Australia, zenon.chaczko@uts.edu.au

[2] Christopher Chiu, Faculty of Engineering, University of Technology, Sydney, Australia, christopher.c.chiu@student.uts.edu.au

[3] Essam Rahali, Faculty of Engineering, University of Technology, Sydney, Australia, essam.rahali@student.uts.edu.au

## ABSTRACT

This paper outlines a concept of employing intelligent agents to simulate, construct and deploy a Smart Library System for an educational facility. Discussion into the many technical challenges driving the concept, ideas behind this approach and the final design rationale are examined. The design model of the Smart Library System that uses Multi-agent simulation and distributed middleware frameworks can be successfully applied to many similar application areas as a means of automating a wide variety of asset monitoring and control tasks in both traditional and distributed systems concerns. Educational environments containing material such as books, multimedia and laboratory equipment can benefit from the proposed software solution allowing such assets to be efficiently managed and monitored. This subsequently would improve the quality of teaching and training support.

***Keywords:*** Software Engineering, Intelligent Agents, Simulation, Education, Asset Inventory System, Information Technology

## INTRODUCTION

Despite the positive advances in ICT technology, the inventory control methodologies employed in today's libraries, laboratories or workshops at educational institutions require manual verification by support staff when performing periodic stock-takes. The hidden labour cost of support staff to locate inaccessible items, returning misplaced items to their original location and basic theft prevention tasks such as bag inspections can result in the decreased efficiency of support staff to assist the individual requests of students or teaching staff. In many cases, the quality and reliability of the stock-takes need to be taken into consideration when environmentally sensitive or precision resources are audited [22].

The development of autonomous wireless sensors in the past decade, in terms of cost, performance and component size, has reached a point where the practical application of this technology in educational environments 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 faculty support staff due to natural attrition, all add to the overall cost of providing student support in educational environments [22]. Therefore, inventory control tasks, such as stocktaking, resorting and theft prevention, increase proportionately in terms of labour costs as the size of a laboratory or library's inventory increases.

The implementation of software intelligent agents in simulating support service scenarios is a progressive step in software engineering. The research project is designed to model various concerns in educational and training environments in order to demonstrate the feasibility of using intelligent agents to aid asset management decisions in educational institutions. By determining the essential requirements to build a framework in which the simulation can operate in a set of pre-conditions, the project aims to simulate the practical application of using wireless sensors in library or workshop environments, coupled with traditional monitoring systems such as closed-circuit television, entry gates or various check points.

The theoretical potential of wireless sensor networks (WSN) can be viewed from beyond traditional inventory control technologies, such as bar-coding and RF security sensors [23]. The project aims to develop a practical implementation of how a sensor network environment can be simulated effectively with software intelligent agents in the domain of an educational institution.

## EXAMINING INVENTORY SYSTEMS IN EDUCATIONAL INSTITUTIONS

The development of novel systems to meet the special needs of educational environments can be built around existing industry knowledge of sensor network technologies and driven by scientific initiatives for Smart Systems in educational institutions [9, 10]. The demand for the implementation and development of such systems cannot always be met by commercial software houses, so there is a considerable interest to appoint local staff to manage and direct the effort. These staff however, would have limited experience in designing, coding, configuring, interfacing and installing traditional systems and frequently would not have experience in management responsibilities.

Thus an emphasis training in the simulation and modelling should be a priority in the final model, for the institutional leaders to provide feedback as to the authenticity of the simulation model.
The fundamental concepts to be examined in realising the Smart Library System are as follows [22, 23]:

- The 'Smart Library' refers to the library's automation of procedures. The context of an educational library with distinct, physical collections is the scope of this research topic.
- Libraries are record-intensive as each title varies, and the records needed for library operations are specific with individual copies of each title.
- Library records must be concerned with specific individual copies of books or journals; a library that does not know which titles it already has and the total copies could not function efficiently.
- Each library serial record contains unique details of each item, including the total issue copy and item particulars including ISBN serial numbers, the title, author and publisher.

For these main reasons, the automation of record-keeping and the management of assets in a library reaffirm the need to ensure that records remain accurate and consistent. Furthermore, the automation of record-keeping in libraries allows the decentralised access to records. Librarians and borrowers can verify a book's loan status and its location without being physically present to check if it is on the shelf.

The 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 books on the shelf, and ensuring the correct sorting order are typical examples of manual procedures accomplished in libraries that are prone to error.

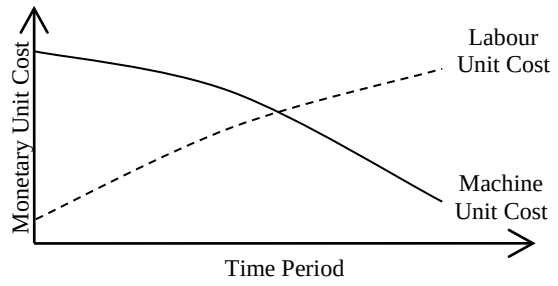


***Fig. 1:*** *Cost Trends of Labour and Technology [23]*

The common assumptions that are made in the context of modern technology in planning ahead for future concerns are listed below [22, 23]:

1. **Computational Efficiency:** Improved computing performance leads to lower cost of ownership of computing systems. This results in the increased accessibility to computers by the end-user.
2. **Automated Inventory Monitoring:** Wireless sensor network technologies will become more ubiquitous and easily deployable in confined or restricted spaces, thus leading to improved optimisation in deployed on a wide scale. Existing bar-coding technology requires line of sight scanning and requires manual operation.
3. **Data Storage Capacity:** Storage costs decrease as data capacities of storage mediums increase per unit cost. Data access rates to these storage mediums continue to improve.
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 inefficiency.

Providing library services in a typical educational institution continues to be labour intensive, with around two-thirds of a library budget accounting for human resources [24]. The purpose of simulating a Smart Library System is to demonstrate the feasibility of modelling a library environment to examine real-world concerns through multi-agent systems. The project aims to gather and structure the simulated data through data mining techniques to determine the information that would be most suitable for aiding in planning decisions of the educational institution.

The practical implications for implementing the system will be based on the final project implementation. The main focus is the feasibility of using the simulated data to convey the information to the educational directors in such a fashion that would influence future planning decisions, as such to optimise operational efficiencies.

## SMART LIBRARY 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 following component concerns are examined in detail:

- **Review of Underlying Technologies:**
  To examine the underlying hardware technologies used in the Smart Library System through wireless sensor networks. The distributed nature of sensor networks lends itself to develop 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.
- **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 educational facility's directors to review the modelling scenario, such as to fit with their operational concerns.

- **Development of a Software Prototype:**
  The implementation of the system will ascertain the degree of interaction of institutional leaders to make decisions for the needs of the educational 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 institution to make relevant decisions can affect the quality and accessibility of teaching material for students. Educational resources need to recognise and be consistent with current teaching methods and theories to provide academic relevance, particularly for research students. Records that are consistent with the usage patterns of library assets are an important resource to understand the practical value of the educational resources to the student and academic community.

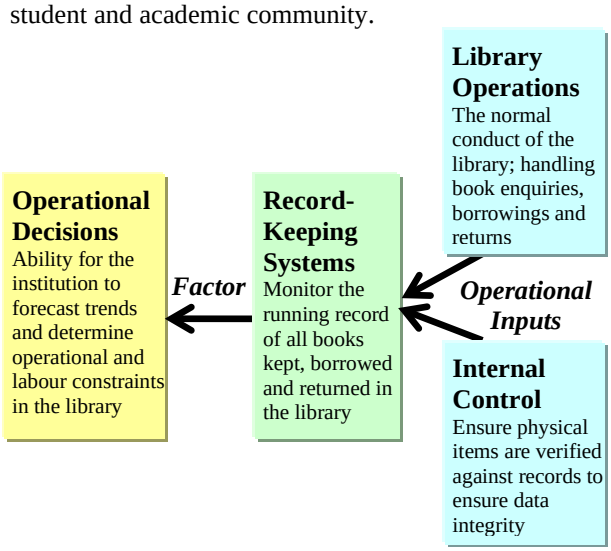


***Fig. 2:*** *Operational Decisions Flowchart [22]*

Computerised record-keeping systems are currently used to libraries obtain the necessary information to make operational decisions in educational institutions. As shown in Figure 2, the record-keeping systems maintain a current record of the books, multimedia and journals held by the library. This record is maintained by a computerised borrowing system, integrated into 'self-serve' kiosks or accessed by library staff directly, to ensure that books borrowed and returned are accounted for throughout the operation of the library.

While computerised record-keeping management has modernised the process of library transaction procedures, internal control is still necessary to ensure current records of material held in the library are consistent. The annual or periodic stocktaking of a library is a core element of internal control to ensure if any discrepancies exist between the library records and the physical books or materials kept by the library at any given time.

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

## DEVELOPMENT METHODOLOGY

The development of the Smart Library 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) where theory is informed by industrial and commercial practice [12, 13]. The Federal Government accredited program has been recognised as embodying world leading standards and practices, the 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 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:

**1. Software Technologies:**
The design of Smart Library System is based on the multi-agent simulation system by AnyLogic [25]. AnyLogic is a commercial software application that generates the graphical agent-based models into Java code stubs. The code stubs can be extended and customised for further development by importing the main business libraries into the NetBeans Java Integrated Development Environment.

The main 'root' object of the software agent forms the basis of which additional software agents are added together to suit the simulation model, which is instances of Java objects in a vector array to achieve multi-agent capability. Interactivity between agents is achieved by setting up '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.

## 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 [12].

- **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:** Implemented on all documentation produced, with the versioning rules based on incremental document revisions, according to minor/major document modification.

## 3. Software Analysis and Design:

The formal analysis of the Smart Library system is categorised by the identification of major stakeholders in the system. This will assist in the requirements 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 Library 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 institutional leaders 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 their requirements fulfils 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 Educational bodies that supervise academic standards and budgetary concerns. The stakeholder is in charge of enforcing legislation and/or institutional by-laws may affect the final product release.

## 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 Library System. This is examined through presenting the project results and artefacts.

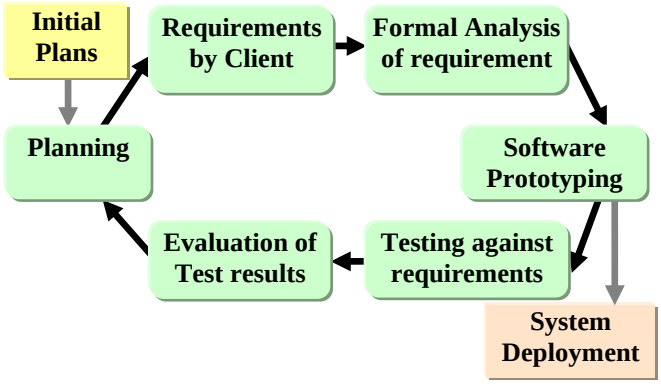


***Fig. 3:*** *Iterative Software Development Model [21]*

The project was implemented according to a tailored prescription of the iterative development model [21]. 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 continually factored into the software implementation to satisfying the iterative philosophy of prototyping, as can be viewed in Figure 3.

An important factor throughout the project development strategy was to consider the change in scope as the project 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 Library System. The functionality of the simulation was included incrementally as the prototype was demonstrated with the end-users of the system.

## 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 Library System. The system's software architecture is based on a distributed architecture. A distributed architecture would allow simulation agents to invoke a remote object just like 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 Jini Middleware System, 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 Jini Protocol, which implements the Java RMI mechanism.

## EFFECTIVENESS OF THE CONCEPT

Through an agent based approach to software system analysis, design, simulation and delivery there are significant benefits to the developers and users of the system. In addition to this there are a range of economic advantages that benefit the educational community. These advantages have many dimensions that may pertain to effective use of ICT technology in education and possible business applications:

- **Strategic Advantages:** There is a net community benefit from improved management and increased awareness of critical projects through applications failing less often, or perceived to fail less often. It is common that the organisation is not rewarded directly through higher reliability, scalability, robustness, maintainability, usability and so on, 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.
- **Commercial Applications:** There is a strong potential for adaptation of similar to Smart Library System to venture into commercial organisations.

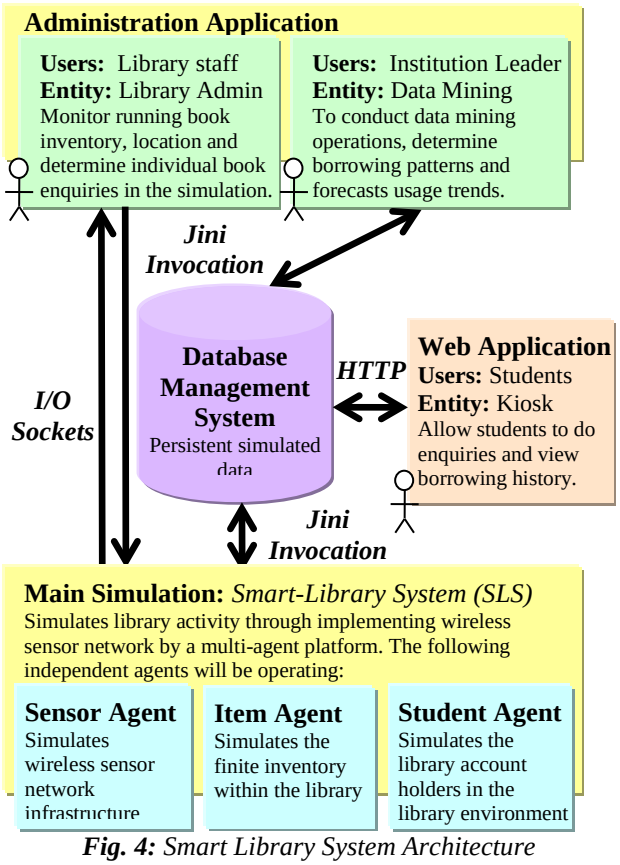


***Fig. 4:*** *Smart Library System Architecture*

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

The design of the Smart Library System emphasises user customisation, in that scenarios can be created to suit the unique layout of the library. Items can be placed at any given area of the grounds, while pre-defined item behaviour will affect the library account holder's interaction to borrow or return the item.

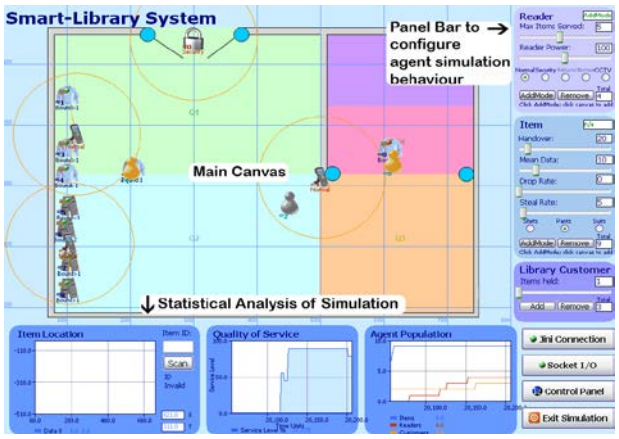


***Fig. 5:*** *Smart Library System Application*

The Smart Library System in Figure 5 graphically displays transaction events, in which real-time activity including book enquiries and stock-takes are handled by administration application. Non real-time events, such as borrowings/returns and item tracking are saved to the database for data mining processes and library activity forecasting. Statistical graphs present the real-time state of the simulation in terms of quality of service. This is concerned with the wireless infrastructure's capability to handle transaction events in the library's daily operations.

## CONCLUSION

The Smart Library System, through its design and implementation, achieves its objective of providing an accessible and effective software simulation for managing assets of educational institutions. 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 library environment can be developed which 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 an educational institution. The simulated data can be examined externally through data mining to plan item placement strategies and forecast future transaction trends.

## ACKNOWLEDGEMENTS

We would like to acknowledge the contribution of Michael Tran, along with Dr Perez Moses and Marina Capponi for their practical experiences and insights into the project.

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