A Smart Healthcare Supply Chain Information Visualisation Platform Based on Digital Twin Technology

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Abstract: By building a unified purchase order-driven information visualisation platform for the smart healthcare supply chain, it can effectively break down information silos and maximise the benefits of each node in the supply chain. The objective of this paper is to study the design of a smart healthcare supply chain information visualisation platform based on digital twin technology. The objectives of supply chain information flow management are studied, different system functional modules are divided through business analysis, a virtual warehouse modelling method based on digital twin is designed, and the composition of inventory information management sub-module based on digital twin is studied to realise the visual control of the virtual warehouse. Performance tests were conducted on the interface of the smart medical supply chain information visualisation platform, and the experimental results showed that the platform has usability and stability.

1 INTRODUCTION

With the continuous reform of China's medical system and the vigorous development of the socialist market economy, the government requires enterprises to provide drug supervision departments with full monitoring and traceability of drugs from purchase to supply and to final acceptance and use, and to strictly monitor price changes in the drug distribution chain to achieve openness in the purchase of medical drugs. To ensure the safety and quality of medicines, and to prevent the price of medicines from being increased at multiple levels in the process of distribution, resulting in inflated prices and ultimately increasing the cost of treatment for people (Kiran, 2022; Yousef, 2020). To improve the overall level of service in the national healthcare sector and to ensure the quality of medical drugs through monitoring (Chaithanya, 2019).

In order to improve the management of medicines and to increase the efficiency of their distribution, Diéssica Oliveira-Dias has optimised the processes of procurement, logistics and medicines management according to modern logistics theory. As a sub-system of the HIS, a new software for the pharmaceutical supply logistics system has also been developed. Seven measures were taken in the area of healthcare supply chain management and the initial establishment of an in-hospital logistics system. All these measures have produced very satisfactory results. Based on a high level of HIS, optimising the medical supply chain process and building an in-hospital logistics system can improve the management of medicines (Diéssica, 2022). Other scholars have analyzed the negative impact of the traditional "zero inventory" management model of high-value medical consumables on medical quality and medical safety, introduced the measures taken by Fu Wai Hospital to strengthen the supply chain management of high-value medical consumables in order to ensure medical quality and medical safety, and discussed the prospects of supply chain management of high-value medical consumables (T. S. Deepu, 2022). Ryan Atkins further elaborated on the digital twin concept of health and medical software product information management in relation to regulatory requirements, FDA and EU Unique Device Identification (UDI) systems, and software product lifecycle management. In addition to illustrating the digital twin concept, we present the advantages and limitations of digital twin-based

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approaches to health and medical software design and development. The approach intentionally requires better support for agile development techniques than classical software development in this application area (Ryan, 2022). Thus, it is necessary for hospitals to implement a hospital supply chain management system to manage and monitor procurement in a uniform manner, both at the level of national policy and from the hospital itself to improve competitiveness and reduce costs.

The innovation of this thesis is to build the platform architecture of digital twin technology based on the smart medical supply chain information visualization platform from the perspective of digital twin technology application, systematically introduce the relevant technology of the platform, and design the inventory information management sub-module based on the twin warehouse model based on digital twin, and explore the relevant medical supply chain business applications by combining the current practical needs and development trend of smart medical. It explores the business applications of the medical supply chain, which will provide the theoretical and technical basis for the application development of medical supply chain information.

2 DESIGN OF A SMART HEALTHCARE SUPPLY CHAIN INFORMATION VISUALIZATION PLATFORM BASED ON DIGITAL TWIN TECHNOLOGY

2.1 Objective of Supply Chain Information Flow Management

Supply chain information flow management is to integrate the information of each end enterprise in the supply chain and establish a close and smooth information flow network, so as to reflect the traceability of products and improve the operational efficiency of each link. In the pharmaceutical industry, supply chain information flow management is the integrated management of a system formed by information on production, quality, inventory, market demand, customer data, distribution and other operational aspects (Cephas, 2022; Roman, 2022).

Supply chain inventory management is a development of traditional inventory management, linked and distinct from each other, with its own characteristics (Pham, 2022). It requires consideration of how to minimise the cost of inventory rather than the total cost, how to co-ordinate with other enterprises and do a good job of cooperation rather than operating independently, and the uncertainties of various aspects. To maximize the benefits of each node of the supply chain (Michael, 2022).

2.2 Digital Twin

The digital twin consists of two kinds of digital optimisation drives, one model-driven and one data-driven, i.e. a digital model or enhanced data constitutes a suitable solution to an industrial application problem (Tal, 2021). The focus of digital model simulation is different from that of traditional model simulation, which is concerned with the fidelity and reproducibility of the model, i.e. whether it can accurately reproduce the properties and state of the physical object. Digital model simulation, on the other hand, is more concerned with the changing relationships during the dynamic simulation process. Data-driven simulation is the opposite. Data-driven simulation in digital twin technology is more concerned with the authenticity and accuracy of the data in the simulation process, while the data generated in the traditional simulation process is to a certain extent for the reference of simulation researchers only (Alok, 2021). In this paper, we use the features of digital twin technology to replace the physical entity with a virtual model to monitor the inventory status of the warehouse more intuitively through 3D modelling by collecting operational data of the warehouse environment.

2.3 Virtual Warehouse Construction Process

According to the characteristics of the real mapping of the digital twin, the digital model of the server room is the digital twin of the physical object of the server room. This chapter uses Blender and three.js together to model the way to design the virtual server room model, server room modelling specific implementation steps are as follows:

(1) Model building of the server room

The model is then edited, resized and rendered in Blender software, while the texture maps of the machine room equipment are collected and optimised by PS. The optimised images are then applied to the surface of the model and the real machine room equipment model is rendered (Mustufa, 2021).

(2) Machine room scene layout

Export the server room model to three.js and add physical effects to the model, such as collision detection, friction, elasticity and other effects, to make the model more in line with the real server room. Layout the equipment in the machine room under the same coordinate system to achieve consistency between the layout of the machine room 3D scene and the actual machine room layout (Hakim, 2021).

(3) Optimisation of scenes

Using scene loading optimization and model rendering optimization means to accelerate the rendering of scene models and improve the system operation rate.

(4) Scene model visualisation

Display the server room scene model to the browser interface through programming language. In addition to the above equipment and scene visualisation of the server room, the system should also contain other visualisation information of the server room, such as server room overview visualisation, asset visualisation, motion loop visualisation, alarm visualisation, etc. Such visualisation information is displayed on the interface in real time through the status kanban board (Sahar, 2021).

3 INVESTIGATION AND STUDY OF A DIGITAL TWIN TECHNOLOGY-BASED INFORMATION VISUALISATION PLATFORM FOR THE SMART HEALTHCARE SUPPLY CHAIN

3.1 System Architecture

The system is developed using the C/SClient/Server() architecture model, the main components of which are the client and the server. When going to the production site to deploy the system, not only do you need to install the database on the server, you also need to deploy the system services, after which you need to install the client on the client machine. This architecture model has two main advantages: firstly, it runs faster and with less lag, and secondly, it makes full use of client machine resources. The architecture of a digital twin-based rapid response manufacturing system can be divided into four main parts: the user interaction layer, the system functionality layer, the object layer and the support layer.

(1) User interaction layer

The core technology of the user interaction layer is to realise the human-computer interaction between the operator and the software system. It contains various applications and interfaces on the client side, through which the user can edit and process data and information, most of which will be displayed to the user in the form of diagrams, tables and virtual scenes.

(2) System function layer

The system function layer is the core of the entire digital twin-based rapid response manufacturing system and contains most of the programs that implement the business logic. It receives information data from users and production sites through data interfaces, processes the information data and is also responsible for issuing instructions to production sites.

(3) Object layer and support layer, the

The object layer and support layer use the open source NHibernate framework for database connectivity, which aims to manipulate data by establishing a mapping of entity classes of database objects and thus data manipulation, the core of which lies in the manipulation of the underlying data and data storage.

3.2 Twin Warehouse Model

The movement of the model in the virtual warehouse mainly translates, rotates and scales the 3D model equally. The 3D model represents the spatial position of each vertex by coordinates and changes the coordinate vector to achieve the motion of the 3D model. The initial position P = (x, y, z) is expressed as (x, y, z, 1) and the transformed position P' = (x', y', z') is expressed as (x', y', z', 1), the translation, rotation and scaling of the 3D model can be expressed by equation (1) as follows.

$$P' = PM = (x, y, z, 1)\begin{pmatrix} b_{11} & b_{12} & b_{13} & p_x \\ b_{21} & b_{22} & b_{23} & p_y \\ b_{31} & b_{32} & b_{33} & p_z \\ t_x & t_y & t_z & s \end{pmatrix} \quad (1)$$

Where M is the four-dimensional coordinate transformation matrix, by changing the four-dimensional transformation matrix can manipulate the three-dimensional model for movement, translation transformation, three-dimensional model from point P to P' point, the transformation process can be seen in equation (2).

$$P' = PM = (x, y, z, 1)\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ t_x & t_y & t_z & 1 \end{pmatrix} = (x + t_x, y + t_y, z + t_z, 1) \quad (2)$$

The tx, ty, tz in equation (2) represent the distance the model travels along the X, Y and Z axes respectively.

4 ANALYSIS AND RESEARCH OF A DIGITAL TWIN TECHNOLOGY-BASED INFORMATION VISUALIZATION PLATFORM FOR THE SMART HEALTHCARE SUPPLY CHAIN

4.1 System Functional Module Design

The main modules of the hospital supply chain management system based on digital twin technology are divided into four main modules: permission management, procurement management, item management and supplier management as shown in Figure 1, and a number of sub-functions are subdivided under these four main modules as described below.

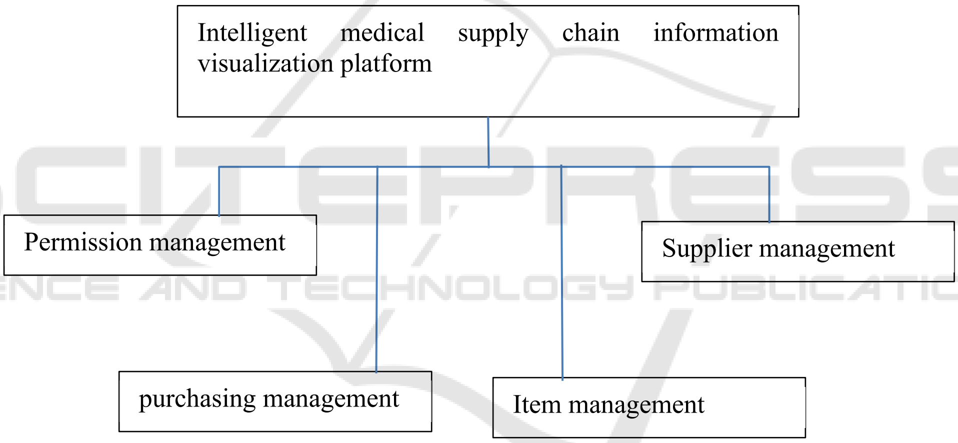

Figure 1: System Function Module

There are four sub-modules involved in the Permissions Management module, namely User Management, Role Management, Task Management and Function Management, of which User Management is mainly used to manage the basic information of users and their role assignment information. The role management module not only needs to manage the basic information of the role but also needs to have the function of managing users under the role and the function of assigning tasks to the role.

The procurement management module contains eight main sub-modules, namely pending items, inventory information management, purchase plan creation, purchase plan review, purchase order response, purchase order creation, purchase order confirmation and purchase order acceptance. Pending items are mainly for the user to show the pending items in the procurement management process such as suppliers need to see their supply applications and supply orders to be responded and shipped, while the warehouse owner needs to see information such as pending audits, new purchase plans and supply applications from suppliers. The Inventory Management module provides the user with the ability to view the inventory of items, and also provides the ability to set maximum and minimum stock limits, which needs to be synchronised with the hospital on a regular basis to share inventory data.

The item management module is mainly for managing the information of hospital items. In this module, users can add, delete, change and view the item information and other basic operations.

The supplier management module mainly involves five sub-modules: supplier information management, qualification application, qualification audit, SMS records and qualification testing. The supplier information management module is mainly used to maintain the basic information of suppliers, and the qualification application module is mainly used to enter the supplier's qualification certificate information and upload the corresponding pictures.

4.2 Components of the Digital Twin-based Inventory Management Sub-module

The inventory information management sub-module of the digital twin-based procurement management module consists of four main components, namely physical inventory, virtual inventory, inventory service system and inventory twin data. Physical inventory mainly refers to the actual warehouse site, which is an objective physical collection of inventory, including equipment resources, material resources, tooling resources, etc. Virtual inventory is a digital representation of the physical production line and is a faithful digital mirror of physical inventory. Its function is to monitor, forecast and control inventory in real time. The inventory service system is a collection of data-driven service systems that receive the inventory data uploaded by the inventory twin and use it to provide support and services for the digital control of inventory, such as management control and optimisation services. The inventory twin contains data related to physical inventory, virtual inventory and inventory service systems, as well as data derived from the fusion of the three, and is used to drive physical inventory, virtual inventory and inventory service systems.

4.3 System Performance Testing

Prior to the performance testing of the smart healthcare supply chain information visualisation platform, a certain amount of basic data was first created for the main information tables, including 1000 items of supplier information, 1000 items of item information, 1000 items of purchasing plan, etc. After completing the data construction, the main functional interfaces of different modules of the system were stress tested. Ensure that the system performance meets the requirements.

After the performance test of the system, the response time without concurrent system will be 400ms~700ms, as shown in Table 1.

Table 1. Performance Test of Functional Interfaces of the System

Monitoring point	No concurrent system response time (ms)	100 Concurrent system response time (ms)	200 Concurrent system response time (ms)
1	692	714	1021
2	495	772	924
3	528	777	854
4	600	834	955
5	514	701	914

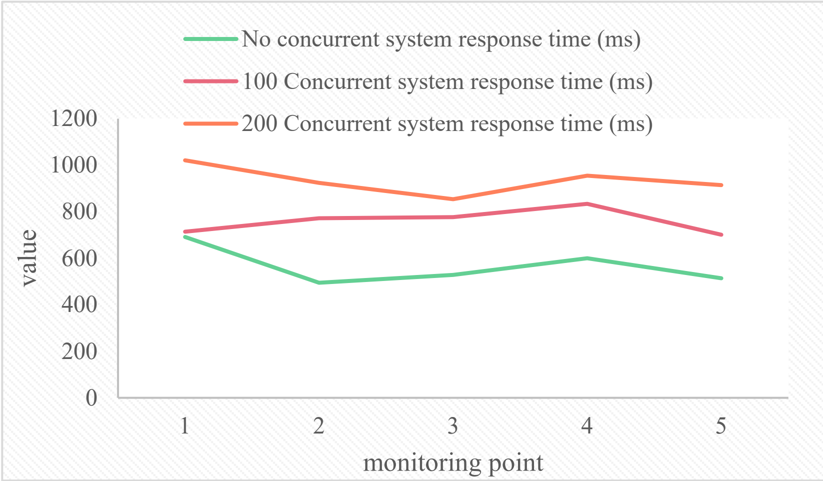

Figure 2: Test Results.

As shown in Figure 2, which is a performance test of some of the important interfaces of the system with different response times under different numbers of concurrency, it can be concluded that most of the interfaces can achieve a response speed within 1000ms with less than 200 concurrency. The requirements for non-functional requirements are met.

5 CONCLUSIONS

In order to improve the level and quality of healthcare services in hospitals, the entire supply chain of items in hospitals needs to be extended to ensure the traceability of medical drugs and equipment and to improve the efficiency of the entire depot procurement. Therefore, the main implementation of the smart medical supply chain information visualisation platform proposed in this paper is based on digital twin technology, which enables the sharing of basic inventory and other information between suppliers and hospitals. Due to the lack of time and limitations of the authors' capabilities, as well as the immature development and application of medical big data, the research is inevitably deficient, and the main issues are as follows: With changes in the medical environment, the gradual development of big data technology and changes in the policy system, the key technologies and main business applications of the smart medical supply chain information visualisation platform also need to be continuously adjusted, optimised and improved in line with the actual situation and needs.

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