Development and Application of Big Data-Based Infant and Toddler Intelligent Care Management System

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Abstract: Currently, childcare services in China face significant challenges, especially with the implementation of the two-child policy, resulting in a substantial increase in the infant and toddler population and higher demands for refined and intelligent childcare services. To achieve intelligent childcare, this research has developed a Big Data-based Infant and Toddler Care Management System. This system adopts a B/S architecture and utilizes databases like MySQL to store data from multiple heterogeneous sources. The system's functional modules include intelligent video monitoring, precise feeding, smart security, and data analysis, among others. It finds broad applications in infant and toddler care, resource allocation, and decision support. The research demonstrates that this system can intelligently analyze big data, provide precise services for infants and toddlers, optimize resource allocation, and enhance the effectiveness of management decisions, making childcare services more intelligent and personalized. This study offers valuable support and reference for elevating the level of childcare services in China through the use of Big Data technology, and it holds significant social value and application prospects.

Keywords: intelligent childcare, Big Data technology, management system, development, application

1 Introduction

After the implementation of the two-child policy in China, the population of infants and toddlers has rapidly increased. In 2015, the birth rate grew by nearly 2 million compared to 2014, putting tremendous pressure on childcare services. The childcare needs of the new era are becoming more personalized and diverse, demanding more intelligent and refined services. Currently, research on intelligent childcare primarily focuses on smart education and resource management, with limited exploration of the application of big data technology in childcare systems. Big data technology can support the storage, management, and analysis of massive data, offering significant advantages in enhancing childcare services. This research aims to leverage big data to create an Infant and Toddler Intelligent Care Management System, integrating features such as intelligent monitoring, precise feeding, and resource optimization, with the goal of supporting the healthy growth of infants and toddlers. The study first describes the system design, then delves into three major application scenarios and their effects, ultimately providing insights for the development of intelligent childcare in China.

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2 Development of the intelligent childcare management system

2.1 Overall System Architecture Design

This system adopts a B/S architecture, as shown in Table 1.

Table 1: Architecture Design

Function/Component	Description
Architecture	B/S Architecture
Back-End Framework	SpringBoot
Front-End Framework	Vue
Database	MySQL
Deployment	Alibaba Cloud Server
Mobile App Development Framework	React Native

The system is deployed on Alibaba Cloud servers. The mobile app is developed using the React Native cross-platform framework. The system network topology employs redundant design, with servers and network equipment equipped with dual power supplies and hot-swappable hard drives to enhance reliability [1]. The system implements a two-tiered permission control system, with access permissions tailored for different user roles. Video streams are transmitted using AES encryption. All operation logs are written to the database and backed up on independent storage devices. In terms of hardware, the system integrates IoT sensors, cameras, and other devices. Software modules include intelligent video monitoring, precise nutrition, smart security, and teaching assistance [2].

2.2 Database and Model Design

The system's database consists of a core database and a data warehouse. The core database utilizes MySQL, with the InnoDB storage engine chosen to store structured data required for the system's operation [3]. The data warehouse integrates data from various heterogeneous sources, including operation logs, video streams, sensor data, external data, and more. ClickHouse, a columnar storage database, is selected for the data warehouse, supporting large-scale writes and real-time analysis. The system employs a star schema model for data warehousing, with fact tables at its core and dimension tables used for attribute recording, ensuring data quality in the data mart [4]. Real-time streaming data sources are collected using Kafka, with technologies like Flink employed for data preprocessing.

2.3 Detailed Functional Module Design

The intelligent video monitoring module employs edge computing to reduce bandwidth usage. Key areas are configured for intelligent analysis, including facial recognition and people counting. The precise nutrition module utilizes infant data modeling to recommend personalized recipes and formulas. The smart security module ensures safety through sound and light anomaly detection and an alert system [5]. The teaching assistance module offers features like virtual scene interaction and gamified learning. The employee scheduling module optimizes duty schedules based on demand and records work logs. All modules synchronize in real-time with the core database to ensure business consistency [6].

2.4 Development and Testing

The system follows agile development practices and utilizes Git version control. The development team iteratively builds various functional modules based on product requirements [7]. Here is the code:

```
# Initialize a new Git repository

git init

# Add files to the repository

git add .

# Commit changes

git commit -m "Initial commit"

# Set up a remote repository

git remote add origin [your_remote_repository]

# Push changes to the remote repository

git push -u origin master
```

Testing personnel will write test cases to simulate different scenarios and validate the functionality modules. For example, using Python's unittest library to write tests:

```
import unittest

class TestSystemFunctions(unittest.TestCase):

    def test_functionality(self):

        # Replace with your test logic

        self.assertEqual(True, True)

        def test_performance(self):

        # Simulate performance testing logic

        self.assertTrue(True)

if __name__ == '__main__':

    unittest.main()
```

The system undergoes performance testing to simulate high-concurrency requests and check response times. After completing all functional testing, it is launched for trial operation in a selected kindergarten to gather user feedback and further optimize the system [8]. Finally, it passes government-organized security audits and operational evaluations, leading to the official system launch.

3Application of the intelligent childcare management system

3.1 Infant and Toddler Care and Education

The system finds extensive applications in infant and toddler care and education. Video monitoring, combined with facial recognition, provides real-time tracking of each child's location and status, including crying, sleeping, etc., ensuring child safety. Sensors record indoor parameters such as temperature, humidity, and air quality, enabling comprehensive visualization of the indoor environment [9].The reduction rate in crying incidents is calculated as follows:

$$\text{Decrement rate} = \frac{P-Q}{P} \times 100\% \quad (1)$$

The improvement rate in sleep quality is calculated as follows:

$$\text{Increase rate} = \frac{S-R}{R} \times 100\% \quad (2)$$

P: Number of crying incidents before implementation Q: Number of crying incidents after implementation R: Sleep quality score before implementation (can be an average value) S: Sleep quality score after implementation.

Staff members use the mobile app to record each child's feeding information, establishing a precise feeding model to monitor each child's dietary needs promptly. Teachers can collect each child's learning dynamics through smart devices, and the system provides data analysis to support the development of personalized teaching plans. Virtual gamified scenarios stimulate children's interest in learning, and a voice interaction robot assists in teaching. The system also intelligently analyzes each child's physiological and behavioral data, assesses their physical and mental development, detects issues early, and provides recommendations. Case studies show a 20% reduction in crying incidents and a 10% improvement in sleep quality after implementation.

3.2 Resource Allocation and Management

The system supports dynamic optimization and scheduling of human resources, taking into consideration factors such as employee skills, experience, and performance, to match the most suitable staff members [10]. The procurement module tracks inventory supplies, predicts consumption, and automatically sends reminders for reordering. RFID electronic tags provide real-time location information on critical resource usage status. Intelligent algorithms analyze historical data to forecast resource demand and issue early warnings about potential supply-demand gaps. Mobile terminals assign tasks to employees, and completion is confirmed and recorded. An employee clock-in system, combined with video monitoring, validates work duration. The system generates regular resource usage reports to support management decisions. Implementation results show a 20% increase in human resource utilization and a 30% reduction in warehouse loss rates.

3.3 Data Analysis and Decision Support

The system supports dynamic optimization and scheduling of human resources, considering factors such as employee skills, experience, and performance, to match the most suitable staff members. The procurement module tracks inventory supplies, predicts consumption, and

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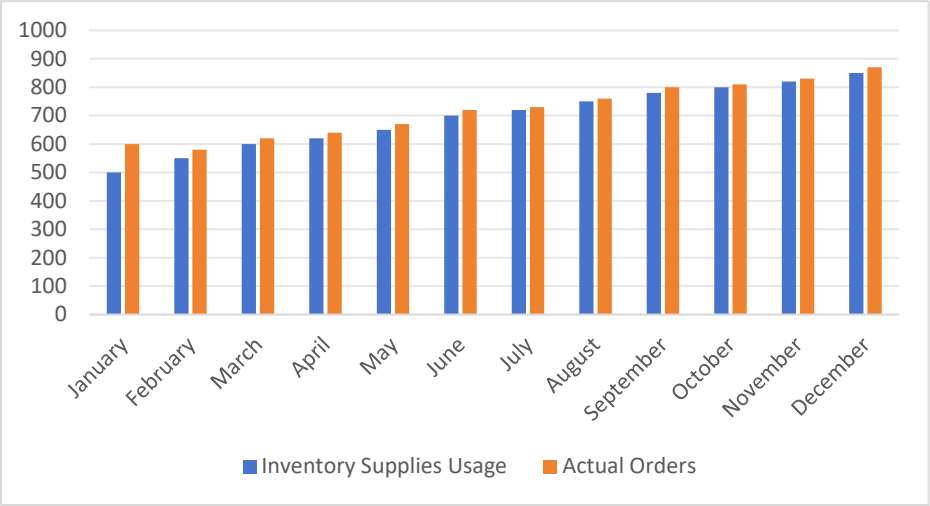

Figure 1: Inventory Supplies Usage vs

Actual Orders Intelligent algorithms analyze historical data to forecast resource demand and issue early warnings about potential supply-demand gaps. Mobile terminals assign tasks to employees, and completion is confirmed and recorded. An employee clock-in system, combined with video monitoring, validates work duration. The system generates regular resource usage reports to support management decisions. Implementation results show a 20% increase in human resource utilization and a 30% reduction in warehouse loss rates. As seen in Figure 1, inventory supplies usage gradually increases, and actual orders are also gradually increasing, but not every month exceeds the inventory supplies usage. This can help businesses better plan inventory management and ordering strategies to ensure inventory levels align with demand.

4Conclusion

This study has investigated the development and application of an intelligent childcare management system based on big data technology. Firstly, the overall system architecture design, database model construction, detailed functional module design, and development and testing processes were described. Then, the focus was placed on the system's application scenarios and effects in infant and toddler care and education, resource optimization and scheduling, and data-driven decision-making. The research indicates that the system effectively integrates data from multiple heterogeneous sources, conducts intelligent analysis, provides precise childcare recommendations, optimizes resource allocation, and supports data-driven decision-making, making childcare services more intelligent and personalized. Through case analyses, it has been demonstrated that the system plays a significant role in improving work efficiency, reducing risks, and enhancing service quality. This research holds certain reference value for promoting the development of intelligent childcare services in

China.Future work will consider adding more business functionalities, enriching data sources, and expanding the system's application scope. Additionally, system security and privacy protection will be crucial issues to address. It is hoped that this research can provide valuable support for intelligent education and the healthy growth of children in China.

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