FULL-PROCESS MANAGEMENT SYSTEM AND METHOD FOR MEDICATIONS AND CONSUMABLES IN INTELLIGENT RESCUE CART INTEGRATING INTERNET OF THINGS AND ARTIFICIAL INTELLIGENCE

Field of the Invention

The present invention relates to the technical field of medical information management, and in particular to a full-process management system and method for medications and consumables in intelligent rescue cart integrating Internet of Things (IoT) and artificial intelligence (AI).

Background to the Invention

In medical rescue scenarios, rescue carts serve as a core carrier for storage and rescue access to medications and consumables, and the management efficiency directly affects the rescue response speed and patient treatment effect. Due to the characteristics of many categories, fast update, high access frequency and sensitivity to the storage environment, the traditional management mode relies on manual inventory recording, manual verification of validity period and environmental status, and there are some problems such as lagging data collection, inaccurate access statistics, and difficulty in timely discovery of abnormal status, which cannot meet the management needs of "real-time, precision and full-process". It is urgent to realize the intelligent management and control of the whole life cycle of medications and consumables through technical means.

Modules of Chinese patent CN202311019494.3 are only simple functional connections, and there is no collaborative link of "data collection-analysis-execution-feedback". It lacks integrated identification and linkage processing capabilities for multi-dimensional abnormalities such as temporary medications and unauthorized access. An alarm module of Chinese patent CN201811580849.5 only triggers reminders for insufficient medications, and is not linked with inventory adjustment, operation traceability and other links. There is no mechanism to feed management results back to a front-end acquisition link to optimize the follow-up management and control, resulting in the rupture of the management process and the inability to continuously improve the control accuracy. In view of this, a full-process management system for medications and consumables in an intelligent rescue cart integrating IoT and AI is provided.

Statement of Invention

An object of the present invention is to provide a full-process management system and method for medications and consumables in an intelligent rescue cart integrating IoT and AI, to solve the problems proposed in the above-described background of data acquisition dimension limitation, lack of multi-source information collaborative perception, weak intelligent analysis capability, difficulty in adapting to dynamic requirements and management processes that do not form a closed loop, and lack of abnormal response and optimization mechanisms.

To solve the above technical problems, one of the objects of the present invention is to provide a full-process management system for medications and consumables in an intelligent rescue cart integrating IoT and AI, including:

an IoT data acquisition unit, in which the IoT data acquisition unit adopts multiple types of IoT sensing devices, and is configured to acquire unique identity information, storage environment status information and access operation behavior information of medications and consumables in the rescue cart in real time, transmit the acquired data to a full-process management unit through low-power wireless communication technology, and retain the original acquired data at the same time, providing real-time and accurate basic data support for full-process management;

an AI intelligent analysis unit, in which, based on historical and real-time data outputted by the IoT data acquisition unit, the AI intelligent analysis unit is configured to realize accurate short-term demand forecasting of the medications and consumables and automatic multi-dimensional abnormal state identification by integrating an improved attention mechanism enhanced long short-term memory network (Attention-LSTM) time series prediction model and an abnormality identification algorithm, providing data-driven basis for management decision-making;

the full-process management unit, in which the full-process management unit is configured to integrate an inventory optimization algorithm and a multi-process control capability based on an analysis result of the AI intelligent analysis unit, and execute warehousing identity binding of the medications and consumables, real-time monitoring of storage status, full-link access traceability, automatic inventory optimization and abnormal event response processing, forming a closed-loop management process of "data acquisition-intelligent analysis-management execution-result feedback"; and

a human-computer interaction terminal unit, in which the human-computer interaction terminal unit adopts a visual interface and authority verification technology, and is configured to display real-time inventory, abnormal warning and traceability records of the medications and consumables, provide medical staff authority management, manual operation triggering and historical data query functions, and realize collaboration between automatic management and manual intervention.

In a further improvement of the technical solution, the IoT data acquisition unit includes an identity recognition module and a multi-parameter sensing module, in which:

the identity recognition module is configured to integrate an ultra-high frequency radio-frequency identification (UHF RFID) reader and a passive RFID tag, the passive RFID tag is prefabricated on a medicine consumable package, and is configured to store unique identification information of generic name, specification, production batch number, expiration date, consumable model and supplier code of the medicine, and the UHF RFID reader activates the passive RFID tag through electromagnetic waves in a 860-960MHz frequency band to realize non-contact reading; and the read identity information is encrypted by the low-power wireless communication technology and transmitted to the full-process management unit in real time, and during a transmission process, a periodic data frame verification mechanism is adopted to ensure data integrity while retaining original records; and

the multi-parameter sensing module is configured to integrate a temperature and humidity sensor, a vibration sensor, an infrared beam sensor and a load sensor, in which:

the temperature and humidity sensor is configured to acquire a temperature and humidity of an storage environment of the rescue cart; the vibration sensor is configured to acquire vibration data of the storage environment; the infrared beam sensor is configured to detect an opening and closing state of a drawer or cabinet door of the rescue cart; and the load sensor is independently set according to storage cells to obtain the access quantity of the medications and consumables by a weight difference; and

environmental state data and access operation behavior data acquired by the multi-parameter sensing module are encrypted by the low-power wireless communication technology (using the same or compatible communication protocol as the identity recognition module 110) and transmitted to the full-process management unit in real time, and during transmission, temperature, humidity and vibration data acquired at high frequency are compressed to reduce power consumption, while retaining original records.

In a further improvement of the technical solution, the AI intelligent analysis unit includes a demand forecasting module and an abnormality identification module, in which:

the demand forecasting module is configured to generate a daily average demand forecasting result $\hat{Q}$ in a preset short-term period of the medications and consumables through an improved Attention-LSTM model based on historical access data and real-time status information outputted by the IoT data acquisition unit, and $\hat{Q}$ includes daily forecasted values in the period; and

the abnormality identification module is configured to analyze the acquired data through a multi-dimensional rule verification algorithm, output an abnormality status identifier Y ($Y = 1$ means abnormal, and $Y = 0$ means normal), and feed abnormality information back to the demand forecasting module.

In a further improvement of the technical solution, the improved Attention-LSTM model includes an LSTM basic network and an attention adjustment layer, in which:

the attention adjustment layer is configured to realize key information enhancement by calculating a weight coefficient α_t of different time steps in historical data, a value range of α_t being [0,1] and satisfying a normalization constraint, in which t is a time step index; and input data received by the improved Attention-LSTM model includes medications and consumables use records in a preset historical period (including access time, quantity and corresponding rescue diseases), department rescue frequency statistical data in the same period and seasonal characteristic information recorded by the IoT data acquisition unit, and a forecast result $\hat{Q}$ of daily average demand of each of medications and consumables is outputted in the preset short-term period after processing, $\hat{Q}$ including daily forecast values $\hat{q}_1$ to $\hat{q}_n$ in the period, in which n is the number of short-term cycle days, preset by the system.

In a further improvement of the technical solution, the full-process management unit includes an inventory optimization module and a process control module, in which:

the inventory optimization module is configured to calculate an optimal inventory threshold and a replenishment quantity through a dynamic inventory algorithm based on the forecast result $\hat{Q}$ of daily average demand and the abnormality status identifier Y outputted by the AI intelligent analysis unit; and

the process control module executes warehousing identity binding of the medications and consumables (associating RFID tag with management system ID), real-time monitoring of storage status (synchronizing sensing data of IoT data acquisition unit), full-link access traceability (recording operator, time, quantity and use related information) and abnormal event response processing (triggering early warning or intervention process when receiving abnormal identification $Y = 1$).

In a further improvement of the technical solution, the dynamic inventory algorithm of the inventory optimization module specifically includes:

safety inventory calculation: calculating a safety inventory threshold S_{safe} by combining a daily forecast value $\hat{q}_i$, historical maximum daily consumption $Q_{\max}$ and abnormality status identifier Y in the short-term forecast result $\hat{Q}$ of daily average demand (when $Y = 1$, a fluctuation coefficient β is introduced);

replenishment trigger mechanism: when an actual inventory balance is reached $Q_{\text{real}} \leq S_{\text{safe}}$, automatically generating a replenishment list, and determining the replenishment quantity R according to a difference between a total demand $\sum \hat{Q}$ in the preset short-term period and a current balance; and

inventory health assessment: through the weighted calculation of an inventory turnover ratio η (total outbound quantity/average inventory) and a proportion of medications in a clinical period θ (number of medications in the clinical period/total inventory), outputting an inventory health index H and synchronizing the same to a visualization terminal.

In a further improvement of the technical solution, the human-computer interaction terminal unit includes a visual display module, an authority authentication module and an operation interaction module, in which:

the visual display module is configured to display an inventory status synchronized by the full-process management unit abnormal warning information outputted by the AI intelligent analysis unit, and access traceability records in real time through a partition interface;

the authority authentication module is configured to adopt a multi-level identity verification mechanism, and is linked with an authority database of the process control module to realize hierarchical management and control of operation authority; and

the operation interaction module is configured to provide manual replenishment trigger, abnormality confirmation processing and historical data query portal, and an operation instruction is encrypted and transmitted to the full-process management unit for execution.

Compared with the prior art, the present invention has the following advantageous effects:

1. The present invention integrates the identity identification module and the multi-parameter sensing module through the IoT data acquisition unit to acquire unique identity information, storage environment state information and access operation behavior information of medications and consumables in real time. The load sensor is independently set according to storage cells to accurately acquire the access quantity, effectively solving the problems of single data acquisition dimension and inaccurate access quantity statistics in the traditional management solution, and providing comprehensive and reliable basic data support for the full-process management of medications and consumables.

2. The present invention relies on the improved Attention-LSTM; time series prediction model of the AI intelligent analysis unit and a multi-dimensional abnormality identification

algorithm. Based on historical access data, department rescue frequency and seasonal characteristics, a short-term forecast result of daily average demand of medications and consumables is generated. Through validity calculation, verification of environmental parameters and permission matching degree check, various problems such as temporary, environment exceeding the standard and abnormal authority are identified, which improves the defects that the traditional fixed threshold early warning cannot adapt to a dynamic demand and it is difficult to find abnormal situations in time, and improves a fitting degree between demand forecasting and actual demand as well as the comprehensiveness of abnormal state identification.

3. With the help of the inventory optimization algorithm and the multi-process control capability of the full-process management unit, the present invention performs warehousing identity binding, real-time monitoring of storage status, and full-link access traceability based on the AI analysis result, and dynamically calculates the optimal inventory threshold and replenishment quantity in combination with the daily average demand forecasting result and the abnormal state to form a closed-loop process of "data acquisition-intelligent analysis-management execution-result feedback", which solves the problems of traditional management process breakage and lack of scientific basis for inventory adjustment, and improves management continuity and rationality of inventory control.

Brief Description of the Drawings

FIG. 1 is a schematic diagram of a system framework of the present invention; and

FIG. 2 is a schematic diagram of steps of a method of the present invention.

Reference numerals and denotations thereof:

100-IoT data acquisition unit; 110-identity recognition module; and 120-multi-parameter sensing module;

200-AI intelligent analysis unit; 210-demand forecasting module; and 220-abnormality identification module;

300-full-process management unit; 310-inventory optimization module; and 320-process control module; and

400-human-computer interaction terminal unit; 410-visual display module; 420-authority authentication module; and 430-operation interaction module.

Detailed Description

Technical solutions in examples of the present invention will be described clearly and completely in the following with reference to the attached drawings in the examples of the present invention. Obviously, all the described examples are only some, rather than all examples of the present invention. Based on the examples in the present invention, all other examples obtained by those of ordinary skill in the art without creative efforts belong to the scope of protection of the present invention.

As shown in FIG. 1, an embodiment provides a full-process management system for medications and consumables in an intelligent rescue cart integrating IoT and AI, including:

an IoT data acquisition unit 100, in which the IoT data acquisition unit 100 adopts multiple types of IoT sensing devices, and is configured to acquire unique identity information, storage environment status information and access operation behavior information of medications and consumables in the rescue cart in real time, transmit the acquired data to a full-process management unit 300 through low-power wireless communication technology, and retain the original acquired data at the same time, providing real-time and accurate basic data support for full-process management.

It can be understood that each component of the IoT data acquisition unit 100 is integrated into the preset mounting slot and storage cell structure inside the rescue cart, powered by the 12V DC power supply system provided with the rescue cart as a whole. At the same time, it is equipped with a backup lithium battery module with a capacity of 5000 mAh. When the external power supply of the rescue cart is interrupted, the backup battery can ensure the continuous operation of the unit for no less than 4 hours, thus avoiding the interruption of data acquisition. The core control board of the unit (integrated data summary and communication scheduling functions) is mounted in an independent waterproof box on the side of the rescue cart box. The protection level of the waterproof box is IP54, which adapts to the environmental needs of the rescue cart during daily cleaning and movement, and prevents water vapor and dust from affecting electronic components.

In the embodiment, the IoT data acquisition unit 100 includes an identity recognition module 110 and a multi-parameter sensing module 120, in which:

the identity recognition module 110 is configured to integrate a UHF RFID reader and a passive RFID tag, the passive RFID tag is prefabricated on a medicine consumable package, and is configured to store unique identification information of generic name, specification, production batch number, expiration date, consumable model and supplier code of the medicine, and the UHF RFID reader activates the passive RFID tag through electromagnetic waves in a 860-960MHz frequency band to realize non-contact reading; and the read identity information is encrypted by the low-power wireless communication technology and transmitted to the full-process management unit 300 in real time, and during a transmission process, a periodic data frame verification mechanism is adopted to ensure data integrity while retaining original records.

Specifically, in terms of hardware adaptation, a passive RFID tag is attached to a conspicuous place of the minimum packaging of medications and consumables, a UHF RFID reader is embedded and mounted on the top of each storage cell, and adjacent readers are staggered in frequency bands to prevent interference. In terms of working logic, when the cabinet door is opened, the infrared beam sensor triggers the reader to scan (stops 3 seconds after closing), and multiple tags are read through time division multiplexing and associated with cell numbers. In terms of data transmission, the identity information is encrypted by AES-128 and then transmitted through ZigBee. CRC32 verification is performed every 10 seconds. If the verification fails, it can be transmitted three times at most. If it still fails, it will be marked as "to be confirmed" and the medical staff will be prompted, and the original records will be kept throughout the process.

The multi-parameter sensing module 120 is configured to integrate a temperature and humidity sensor, a vibration sensor, an infrared beam sensor and a load sensor, in which:

the temperature and humidity sensor is configured to acquire a temperature and humidity of an storage environment of the rescue cart; the vibration sensor is configured to acquire vibration data of the storage environment; the infrared beam sensor is configured to detect an opening and closing state of a drawer or cabinet door of the rescue cart; and the load sensor is independently set according to storage cells to obtain the access quantity of the medications and consumables by a weight difference; and

environmental state data and access operation behavior data acquired by the multi-parameter sensing module 120 are encrypted by the low-power wireless communication technology (using the same or compatible communication protocol as the identity recognition module 110) and transmitted to the full-process management unit 300 in real time, and during transmission, temperature, humidity and vibration data acquired at high frequency are compressed to reduce power consumption, while retaining original records.

Specifically, in terms of sensor deployment, temperature and humidity sensors (such as the corner of each storage layer, 1 minute/time collection), vibration sensors (such as the center of the bottom of the box, 500 ms/time collection), infrared beam sensors (such as a middle line of the edge of the cabinet door, real-time detection switch), load sensor (such as the bottom of each storage cell, covered with 2 mm anti-slip rubber mat + cushion gasket). In terms of data processing, the load sensor calculates the dosage through the weight difference when the cabinet door is opened and closed (the negative difference is marked as warehousing), the high-frequency temperature, humidity and vibration data are compressed losslessly, and all data are associated with cell numbers and the original records are kept.

In addition, the communication of the IoT data acquisition unit 100 can adopt the ZigBee protocol (a single network accommodates ≥ 20 nodes, and the indoor communication radius is ≥ 10 meters). When transmitting across floors, the core control board and the NB-IoT module forwards it, and the data is transmitted according to "abnormal permission data first, conventional environment data later". Data retention adopts a "local + remote" mode, locally stored in the embedded storage of the core control board (retained for 1 year, named according to "collection time-module number-data type"), remotely synchronized to the full-process management unit 300 in real time, and after network interruption, the missing data is supplemented according to the timestamp.

An AI intelligent analysis unit 200 is included, in which, based on historical and real-time data outputted by the IoT data acquisition unit 100, the AI intelligent analysis unit 200 is configured to realize accurate short-term demand forecasting of the medications and consumables and automatic multi-dimensional abnormal state identification by integrating an improved Attention-LSTM time series prediction model and an abnormality identification algorithm, providing data-driven basis for management decision-making;

It can be understood that, the overall deployment and data interaction basis of the AI intelligent analysis unit 200 specifically includes: hardware integration into the hospital's local server or cloud computing power node (adapted to the local deployment of small and medium-sized hospitals and the centralized management needs of large hospitals in the cloud), server/computing power nodes are equipped with quad-core and above processors, 16GB and above running memory, and 1TB and above data storage disks to ensure model operation and data processing efficiency. The unit establishes real-time data interaction with the IoT data acquisition unit 100 and the full-process management unit 300 through Ethernet or the hospital internal dedicated network, and the historical and real-time data acquired from the IoT data acquisition unit 100 are stored in the local database of the unit according to "data type-collection time-associated storage cell", and the integrity is ensured by MD5 verification before data transmission, to avoid data corruption affecting the analysis result.

In the present embodiment, the AI intelligent analysis unit 200 includes a demand forecasting module 210 and an abnormality identification module 220, in which:

the demand forecasting module 210 is configured to generate a daily average demand forecasting result $\hat{Q}$ in a preset short-term period of the medications and consumables through an improved Attention-LSTM model based on historical access data and real-time status information outputted by the IoT data acquisition unit 100, and $\hat{Q}$ includes daily forecasted values in the period; and

the abnormality identification module 220 is configured to analyze the acquired data through a multi-dimensional rule verification algorithm, output an abnormality status identifier Y ($Y = 1$ means abnormal, and $Y = 0$ means normal), and feed abnormality information back to the demand forecasting module 210.

In the embodiment, the improved Attention-LSTM model includes an LSTM basic network and an attention adjustment layer, in which:

the attention adjustment layer is configured to realize key information enhancement by calculating a weight coefficient α_t of different time steps in historical data, a value range of α_t being [0,1] and satisfying a normalization constraint, in which t is a time step index; and

input data received by the improved Attention-LSTM model includes medications and consumables use records in a preset historical period (including access time, quantity and corresponding rescue diseases), department rescue frequency statistical data in the same period and seasonal characteristic information recorded by the IoT data acquisition unit 100, and a forecast result $\hat{Q}$ of daily average demand of each of medications and consumables is outputted in the preset short-term period after processing, $\hat{Q}$ including daily forecast values $\hat{q}_1$ to $\hat{q}_n$ in the period, in which n is the number of short-term cycle days, preset by the system.

Specifically, the linear interpolation completion of 2-3 consecutive pieces of missing data in data preprocessing adopts a formula $y = y_1 + (x - x_1) \times \frac{y_2 - y_1}{x_2 - x_1}$, where y is a missing data value to be completed (such as the number of acquisitions and the associated disease code), x is a missing data index (sorted according to the acquisition time), x_1 is the most recent valid data index before the missing data, y_1 is a valid data value corresponding to x_1, x_2 is the most recent valid data index after the missing data, y_2 is a valid data value corresponding to x_2; and during calculation, the valid data before and after the missing segment is used as the benchmark for fitting and completion, and one decimal place is reserved after completion.

Specifically, the calculation of the average daily demand forecast result $\hat{Q}$ adopts a formula $\hat{Q} = \frac{1}{n}\sum_{i=1}^{n} \hat{q}_i$, in which is an average daily demand forecast result $\hat{Q}$ in a preset short-term period, n is the number of days in the short-term period (the system presets 7 days or 14 days), $\hat{q}_i$ is a demand forecast value on an i day in the period, and $\sum_{i=1}^{n} \hat{q}_i$ is a sum of predicted values in the period.

Specifically, the calculation of the attention weight coefficient α_t includes two steps. First, an attention score is calculated by the following formula:

$$e_t = \text{sigmoid}(W_a \cdot h_t + b_a)$$

where e_t is an attention score of a t time step, W_a is a weight matrix of an attention adjustment layer, h_t is output of a hidden layer of a t time step of LSTM, and b_a is a bias term $\text{sigmoid}(x) = \frac{1}{1+\exp(-x)}$.

Then the attention score is normalized by the following formula: $\alpha_t = \frac{\exp(e_t)}{\sum_{k=1}^{m} \exp(e_k)}$; where α_t is a weight coefficient of the t time step, m is a total time step of historical data, and k is a time step index.

In the embodiment, a process of executing the multi-dimensional rule verification algorithm by the abnormality identification module 220 includes the following steps:

S220.1, data reception: receiving identity information, environmental status data and access operation records of medications and consumables transmitted by an IoT data acquisition unit 100 in real time, and synchronously retrieving original records stored in a full-process management unit 300 for comparison,

S220.2, expiration verification: analyzing a valid period field in the identity information, calculating a remaining valid period T, T being compared with a preset threshold T_0, if $T \leq T_0$, it being marked as abnormal, and a rescue level being divided according to $T \leq T_0/2$ or $T_0/2 < T \leq T_0$,

S220.3, environmental verification: extracting measured values S of temperature, humidity and vibration parameters in environmental state data, and comparing with a preset safety interval $[S_{\min}, S_{\max}]$, if S exceeds an interval and lasts for a duration of $\Delta t \geq t_0$, the environment being marked as abnormal, where t_0 is a preset duration threshold,

S220.4, authority verification: performing matching calculation between access operation records and a verification result in a system authority database to obtain a matching degree γ, if $\gamma < \gamma_0$, marking abnormal authority, where γ_0 is a preset matching threshold, and

S220.5, result integration and feedback: integrating an abnormality identifier of each dimension into an abnormal state identifier $Y = 1$ (when there is no abnormality, $Y = 0$), and feeding additional abnormality types and parameter information back to the demand forecasting module 210 for dynamically adjusting the time step weight coefficient α_t in its model.

Further, the model initialization and update mechanism of the AI intelligent analysis unit 200 according to the embodiment specifically includes: when the unit is started for the first time, the medications and consumables retrieval data, rescue data, and seasonal data of the hospital in the past 1-2 years are introduced, the improved Attention-LSTM model is pre-trained, and the improved Attention-LSTM model is put into use after the deviation between the predicted result and the historical actual data is stabilized within a reasonable range (for example, the deviation rate is < 20%). Every 3 months or after processing 1,000 or more new data in total, the model will be automatically fine-tuned with the newly collected historical data (only the hidden layer weights and attention adjustment layer parameters are adjusted). At the same time, the deviation between the predicted result and the actual data is recorded in real time. If the deviation rate is > 30% for 7 consecutive days, a "model needs manual calibration" prompt is sent to the human-computer interaction terminal unit 400, and the technician will check the data input or adjust the model parameters to ensure long-term operation stability.

The full-process management unit 300 is included, in which the full-process management unit 300 is configured to integrate an inventory optimization algorithm and a multi-process control capability based on an analysis result of the AI intelligent analysis unit 200, and execute warehousing identity binding of the medications and consumables, real-time monitoring of storage status, full-link access traceability, automatic inventory optimization and abnormal event response processing, forming a closed-loop management process of "data acquisition-intelligent analysis-management execution-result feedback".

It can be understood that the logic of hardware deployment and data interaction specifically includes: integration into the local management server of the hospital (sharing server hardware with the AI intelligent analysis unit 200 to reduce the deployment cost), establishing two-way data transmission with the IoT data acquisition unit 100, the AI intelligent analysis unit 200 and the human-computer interaction terminal unit 400 through the internal local area network of the hospital. The transmitted data are encrypted by AES-128, and stored in the unit database according to the classification of "data type (such as warehousing data, inventory data and abnormal data)-timestamp-associated cell". The database supports quick retrieval according to keywords such as drug ID, operation time and abnormal type, which is convenient for medical staff to trace back.

In the embodiment, the full-process management unit 300 includes an inventory optimization module 310 and a process control module 320.

The inventory optimization module 310 is configured to calculate an optimal inventory threshold and a replenishment quantity through a dynamic inventory algorithm based on the forecast result Qˆ of daily average demand and the abnormality status identifier Y outputted by the AI intelligent analysis unit 200.

The process control module 320 executes warehousing identity binding of the medications and consumables (associating RFID tag with management system ID), real-time monitoring of storage status (synchronizing sensing data of IoT data acquisition unit 100), full-link access traceability (recording operator, time, quantity and use related information) and abnormal event response processing (triggering early warning or intervention process when receiving the abnormal identifier $Y = 1$).

In the embodiment, the dynamic inventory algorithm of the inventory optimization module 310 specifically includes:

safety inventory calculation: calculating a safety inventory threshold S_{safe} by combining a daily forecast value $\hat{q}_i$, historical maximum daily consumption $Q_{\max}$ and abnormality status identifier Y in the short-term forecast result $\hat{Q}$ of daily average demand (when $Y = 1$, a fluctuation coefficient β is introduced);

replenishment trigger mechanism: when an actual inventory balance is reached $Q_{\text{real}} \leq$

S_{safe}, automatically generating a replenishment list, and determining the replenishment quantity R according to a difference between a total demand $\sum\hat{Q}$ in the preset short-term period and a current balance; and

inventory health assessment: through the weighted calculation of an inventory turnover ratio η (total outbound quantity/average inventory) and a proportion of medications in a clinical period θ (number of medications in the clinical period/total inventory), outputting an inventory health index H and synchronizing the same to a visualization terminal.

Specifically, the replenishment trigger mechanism and inventory health assessment are as follows:

replenishment trigger mechanism: when an actual inventory balance is reached $Q_{\text{real}} \leq S_{\text{safe}}$, the system automatically generates a replenishment list, and the replenishment quantity R is calculated according to the above formula;

inventory health assessment: through the weighted calculation of an inventory turnover ratio η ($\eta = \text{total inventory quantity/average inventory}$) and a proportion of medications in a clinical period θ ($\theta = \frac{\text{number of medications in clinical}}{\text{total inventory quantity}}$), outputting an inventory health index H and synchronizing the same to a visual interface of a human-computer interaction terminal unit 400, which is convenient for medical staff to intuitively judge the overall state of inventory.

Further, when the full-process management unit 300 receives the abnormal state identifier $Y = 1$ and the abnormal information sent by the AI intelligent analysis unit 200, the process control module 320 triggers a corresponding linkage operation according to the abnormal type, as follows:

When the expiration date is abnormal, the corresponding medication is automatically marked in red/yellow in the inventory visualization interface of the human-computer interaction terminal unit 400, and a prompt of "prioritizing the expiration date medication" is pushed.

When the environment exceeds the standard, in addition to marking the abnormality, a short message reminder will be sent to a mobile terminal of a rescue cart administrator, informing that "the environment of a storage cell exceeds the standard (such as the temperature is 32℃), and the equipment (such as cooling fan and sealing strip) needs to be checked in time".

When the permission is abnormal, the subsequent access permission of the operator is frozen until the administrator verifies and unlocks it; and at the same time, all exception handling records (such as "the environment exceeded the standard on 2024-10-01, the administrator handled it on-site at 14:30, and returned to normal at 14:35") are stored in association with the exception records, forming a closed loop of "anomaly identification-linkage processing-result recording", which is convenient for subsequent management and re-recording.

A human-computer interaction terminal unit 400 is included, in which the human-computer interaction terminal unit 400 adopts a visual interface and authority verification technology, and is configured to display real-time inventory, abnormal warning and traceability records of the medications and consumables, provide medical staff authority management, manual operation triggering and historical data query functions, and realize collaboration between automatic management and manual intervention.

In this embodiment, the human-computer interaction terminal unit 400 includes a visual display module 410, an authority authentication module 420 and an operation interaction module 430, in which:

the human-computer interaction terminal unit 400 includes a visual display module 410, an authority authentication module 420 and an operation interaction module 430.

Specifically, the visual display module 410 presents data in the form of a "partition dynamic interface", and the interface is divided into three core areas: an inventory overview area, an abnormality warning area, and an access traceability record area.

Inventory overview area: according to the physical layout of cells (such as "upper left one" and "middle right three"), the state of each cell is simulated and displayed, and the inventory and abnormal situation of medications and consumables are marked with different colors-green means that the inventory is sufficient and there is no abnormality, yellow means that the medication is in the critical period (corresponding to the results of the critical period verification), and red means that there are problems such as excessive environment and abnormal authority; and next to each storage cell, the generic name of the medication and the remaining quantity are marked (for example, "Adrenaline Hydrochloride Injection, 3 remaining").

Abnormal warning area: sorted by abnormal urgency (red entries are high priority, such as expired medications and continuous environment exceeding the standard; and orange entries are medium priority, such as general temporary medications and single authority verification failure). Each abnormal entry contains abnormal type (such as "environment exceeding the standard-temperature" and "abnormal authority-access"), medication ID involved, and trigger time (accurate to minutes, such as "2024-10-01 14:30").

Access traceability record area: medical staff are supported to search by time range (such as "recent 7 days" and "recent 30 days") and medication ID, and search results are displayed in the form of "timeline list". Each record contains operation type (warehousing/fetching), operation time, operator ID (anonymously displayed as "nurse XXX" and "doctor XXX"), medications involved and quantity, to realize warehousing-storage.

The authority authentication module 420 adopts a multi-level authentication mechanism, and implements hierarchical management and control of operation authority in linkage with the authority database of the process management and control module 320.

Specifically, the authority authentication module 420 adopts a multi-level authentication mechanism of "basic authentication + hierarchical enhancement", and is linked with the "authority database" of the process control module 320 in real time:

Basic verification: when operating for the first time, medical staff need to enter their work number and preset password to complete basic-level authentication, and can use basic functions such as "querying inventory" and "viewing traceability records".

Hierarchical enhanced verification: when high-risk operations such as "manual replenishment" and "special medication withdrawal" are performed, the terminal automatically triggers enhanced verification-the advanced verification is "job number + fingerprint" (the terminal integrates a fingerprint identification module, and after collecting fingerprint information, it is compared with the fingerprint template of medical staff stored in the process control module); and advanced verification is "job number + face recognition" (a front camera of the terminal collects facial images and matches them with the background face database).

Authority linkage and control: the authority database of the process control module 320 stores the related data of "operator ID-operable medication type-operation authority level", such as authority level 1: only be queried; level 2: it can be used for general medications and consumables; and level 3: it can trigger replenishment and take special medicines. After the authority authentication module 420 passes the verification, the authority authentication module 420 sends the operator ID to the process control module 320 to obtain the corresponding authority level, and then dynamically opens a function button, such as a medical staff with authority level 3, on the terminal interface, and the interface displays "manual replenishment" and "special access" buttons. Healthcare workers with permission level 1 only display the "Query" class button.

The operation interaction module 430 provides manual replenishment triggering, exception confirmation processing, and historical data query portals, and the operation instructions are encrypted and transmitted to the full-process management unit 300 for execution.

Specifically, the operation interaction module 430 provides a functional entrance of "manual intervention" for medical staff, and all operation instructions are encrypted by AES and then transmitted to the full-process management unit 300 for execution.

As shown in FIG. 2, an embodiment further provides a full-process management method for medications and consumables in an intelligent rescue cart integrating IoT and AI, based on the above-described full-process management system for medications and consumables in an intelligent rescue cart integrating IoT and AI, including the following steps:

S100, data acquisition and storage: acquiring unique identity information, storage environment status information and access operation behavior information of medications and consumables; and reading the identity information in a non-contact way, obtaining the environmental data by means of perception, calculating an access quantity by a weight difference, transmitting the acquired data by low-power wireless communication, and retaining the original acquired data;

S200, AI intelligent analysis and processing: retrieving the original acquired data, eliminating invalid records due to misoperation, supplementing missing information by an interpolation method of adjacent valid records, aggregating the supplemented data on a daily basis and fusing with rescue frequency and seasonal characteristics of departments in the same period to form characteristic data, extracting time sequence characteristics, calculating weights of historical data in different time steps to strengthen key information, and generating a prediction result of daily average demand of each of the medications and consumables in a preset short period; and at the same time, receiving the acquired identity information, environmental data and access records, comparing with the stored original records, and marking temporary, environment exceeding the standard and abnormal authority by validity period calculation, environmental parameter verification, authority matching degree verification, integrating abnormal identifier generation results and feeding additional type parameters back to a demand forecasting link;

S300, full-process management execution: combining short-term average daily demand forecast results, historical maximum daily consumption and abnormal state, calculating a safety inventory threshold, automatically generating a replenishment list when an actual inventory balance is less than or equal to the threshold, and calculating and outputting an inventory health index by weighting an inventory turnover rate and a proportion of medications in clinical; and synchronously implementing medications and consumables warehousing identity binding, real-time monitoring of storage status, full-link access traceability, and triggering early warning or intervention process when abnormal results are received;

S400, human-computer interaction collaboration: displaying inventory status, abnormal warning and traceability records through partitioned interfaces, adopting multi-level identity verification to realize hierarchical management and control of permissions, providing manual replenishment, abnormal confirmation and historical data query portals, and encrypting and transmitting manual operation instructions to execute corresponding management actions; and

S500, closed-loop feedback optimization: collecting inventory adjustment results and manual operation records, feeding the same back to a data acquisition end to improve original record retention dimensions of identity information, storage environment status information and access operation information of medications and consumables, and feeding the same back to an intelligent analysis end to update a historical data set required for demand forecast of medications and consumables, to finally form a closed-loop management process of "data acquisition-intelligent analysis-management execution-human-computer interaction-result feedback".

Those skilled in the art will understand that the process of implementing all or part of the steps of the above-described embodiments may be completed by hardware, or may be completed by instructing related hardware by a program.

The basic principles and main features of the present invention and the advantages of the present invention have been shown and described above. It is to be understood by those skilled in the art that the present invention is not limited by the above-mentioned embodiments, and the above-mentioned embodiments and descriptions in the specification are only preferred examples of the present invention, and are not used to limit the present invention. Without departing from the spirit and scope of the present invention, there will be various changes and improvements in the present invention, which are all within the scope of the claimed invention. The claimed scope of the present invention is defined by the appended claims and equivalents thereof.