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A Study and Development on Robotic Drug Storaging and Dispensing System in Drug Logistics for A Mid-Sized Hospital

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***Abstract*— this project expresses an idea about distribution medicines by using intelligent system which is included an information system, auto-guided vehicles (AGVs), a robot dispensing. However, this paper is intent to focus and narrow on the robot dispensing system. A robot dispensing system is to minimize staff worked load, increased effectiveness and decrease error. An observation in hospital was performing before implementation the system. Data was collected before and after implantation. All of data were analyzed. By the data continuously collected 30 working days in the hospital. The results are obviously shown that using dispensing robot system is able to minimize concerned problem, increased time efficiency almost 2 times compared with traditional procedure. Dispensing Robot System is trend to improving a management of drug distribution in drug storage. Moreover, staffs in this department are very satisfying this system because of useful for their working process.**

Keyword – Development, Robotic, Drug, Storage, Dispensing System, Logistics, Mid-Sized Hospital, Automation, Pharmaceutical, Management

I. Introduction

A. Background

In medical institute, drug logistic system is very important. A proposes of improving drug logistic system is for efficiency supplying medicines entries medical institute. Procedure starts from suppliers to supply the drugs based on requests from the usages from each department in hospital [1-3, 7]. Normally, medicines are supplied to drug storage department first. After that, medicines would be distributed to other departments such as orthopedic department, medical department upon requirement [3, 4]. As many department in hospital, drug storage would be concerned about accuracy, time efficiency. Good management and logistics are required to improve the process in drug storage [7-10].

Nowadays, basics information technology system and human delivering management system are used in traditional dispending procedure. However, there are some problems in the working process. (1) Filling the data by handwriting onto a sheet of paper to record the stock is a big problem. It could cause mistakes or errors. (2) The recoding by staff is redundant work for them. The overload of work causes fatigue and therefore ineffectiveness. This problem would lead to delay in any step of the process. (3) A problem in medical miscounting the stock level is always found in the drug storage. (4). Overstocking in the pharmacy leads to a problem in the working area of the department. (5) Many documents are paper based, which always leads to problems. This project is attempted to eliminate those problem.

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B. Related Work and Research Observation Literature Reviews

Following these problems, this project would be able to use the knowledge of robotics and automation system [14-15, 17] especially an industrial robot to solve the problems listed above and improve the system. The main propose of this project is to minimize staff workload, increase effectiveness [6-8], and decrease error using an intelligent system [14-17] such as synchronization between information systems [16], robotics system [15-17], automation system [15,16], logistics [14-17] and data management [17]. Hospital size and the medical dispensing processes used [6] are not dependent on each other. No matter the size, a big hospital, medium or small hospitals, all use a similar dispensing process. The main idea is to dispense medicine to the patient using an efficient process and without error.

Propose: To use a robotics and technology improve a dispensing system based on IT, Robotics and Automation Technology. The system includes 2 parts which are the robot/automation system and drug delivery System which are covered by the information system. (See. Fig 1)

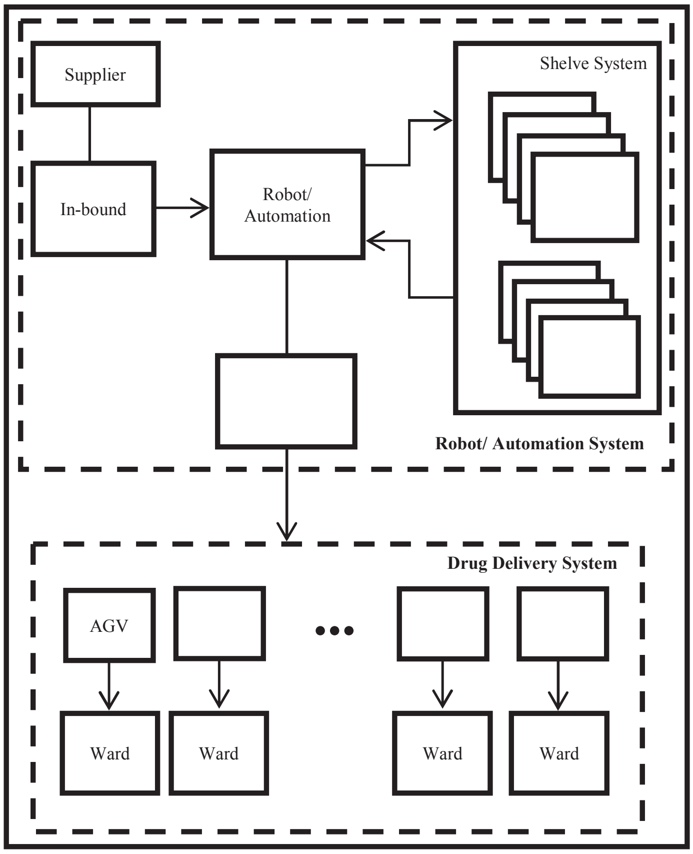


Fig1: Overview of proposed robotic drug dispensing system is covered by various technologies in the system

II. Overview of the Project

Starting with the information system, it will be a tool for managing all the components and helping an administrator, who is a pharmacist or head of the drug storage who is a pharmacist.

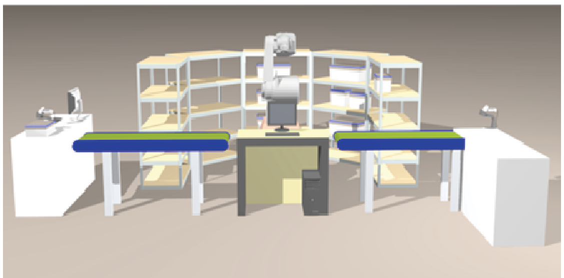


Fig2: Overall system of Robotic Drug Dispensing Using an Industrial Robot

Based on Fig.1, Information Technology covers the overall system including the drug storage. The information system will assist a pharmacist and staffs. It requires just only one pharmacist to monitor the process and approve prescriptions. Furthermore, the pharmacist is able to remotely monitor and approve the requirements. For other parts of this system, such as Auto-Guided Vehicle (AGV), the information system also assists to monitor the AGV process which is a process for carrying medicines to wards. The information system would automatically record and refresh its system ever single minute, depending on setting up. The head of the pharmaceutical department is able to check the locked files, request history of dispenser and the history at each step throughout the process.

III. Drug Dispensing

Step I: In-bound Process

The head of the drug storage would update the stock every week. The spare stock would be set to certain level; this level is dependent on the head of drug storage because the level is adjustable. When the stock reaches below this level, the head will be notified and can order the medicine following the traditional protocol.

In a general case, the medical suppliers send medicines to the drug storage in big paper boxes. The system would initiate at this process. The staff that takes care of this part has to register his/herself by scanning their barcode on the ID card (and by scanning the paper with the order). The staff information would be registered into the database to record and notify the administrator who is taking responsibility for this order. After registering themselves this step is complete, the staff would unpack the paper boxes to register the medicine. When the staff scans a medicine barcode, the packing instruction will be shown on the screen. Staff has to follow the instructions; (1) to register the medicine, instructions to pack in Box A or B will be shown for the specific medicine. (2) to register the cover's box by scanning barcode on it. (3) to put the medicine following the provided instructions. (4) to put the medicine into the box following a number of instruction, until they close the box. It would help and guide the staff until the end of the inbound process. After that, he/she will unpack paper boxes, and repack medicines into the designated boxes; the boxes are specifically designed for our system.

Step II: Storing Process

When the medicine is placed on the conveyor, the infrared sensor detects the box. The conveyor belt will move the box along its pathway. On the conveyor, we provide a stack to arrange the boxes into a nice line. At the end of the conveyor, we have attached an infrared sensor to detect the box's arrival. After the infrared sensor detects the box, the information system will be detecting the medicine arriving at the end of the conveyor. The databank will send some message to the robot's programming. The robot will move its end effector to the position. In case the robot is running some task, it will complete the task at hand first. The robot will move the end effector to the medicine shelf because the barcode scanner is attached on it, the medicine shelf will be scanned and data will be sent to the databank. The information system will calculate and find an empty slot for it. In case the matching is complete, the robot will move its end-effector to grip the medicine package to place it in the designated slot. However, if there is no place, the robot will move the medicine to a temporary shelf which is prepared for certain mistakes.

Step III: Out-bound Process

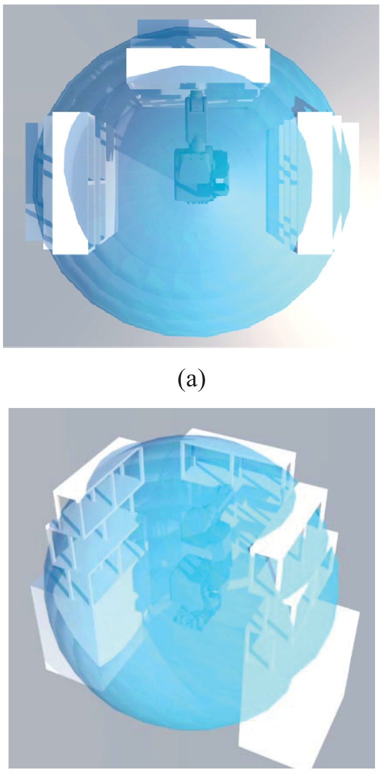
Beginning with the process of ordering the medicine from wards; requirements for the order will be sent to the center of the information system. The system will update every 2 seconds. The administrator is able to monitor and approve the order system to work on. The administrator is the head of the drug storage. She/he just approves the requirement. After it's approved, the robot will move the end-effector to the requested medicine. We have programmed the robot to recheck medicine before the item is grasped. It will use a barcode scanner which is attached to scan and check the medicine. After rechecking is done, the robot will grip the medicine to place on the out-bound conveyor. At the end of out-bound conveyor, we have attached infrared sensor to detect any arriving medicines. The conveyor will move to send the medicine to an AGV. In case of any mistakes; the robot would move the package to the temporary box/shelf.

Step IV: Dispensing Process

At the end of conveyor, we provide a temporary box to keep all medicines. The temporary box is a box for keeping medicines after the robot grips it. Before opening the temporary box, the staff has to identify themselves for security reasons. During the process of dispensing the medicine by the AGV, the staff has to identify themselves before opening the AGV. The information system will inform the user of the steps to complete the task. Volume is 17102.80 units per month, 855.14 units per day and 142.52 units per hour.

IV. Intelligent Shelving System Design

Shelve function was designed based on the functional needs of the store room. We have observed the medical work flow in the store for 30 days. During that period, we received data from the pharmaceutical director. The data includes medical usage, frequency of medical withdrawing, medicine ordering amount from the medical agency. The shelving was designed based on the needs of a high frequency medical ordering from the wards. It would be represented by the medical usage in the hospital. (The data was collected for 30 days and we received the data turn around for the last 5 months 20 days and 2 hours)After the data were analyzed, we found a size for shelves and a size for the medical packages. The data shown about the highest frequency of drug order is shown in the table below. It is used to design shelves, number of slots, and other essential aspects of the design. Following the table, we know about the statistics of 20 working days the usage in various seasons, months, and other factors. Then, we should design the robot and shelves based on number of drug used per month. We used this information to design the system. For an effective shelving design, the work space of the industrial robot is required. We need to combine the workspace of the robotics system, shelving system, and work flow system to the overall system. The shelves should be designed based on the following requirements: (1). an easy access for robot without any problems. (2). It should fit various sizes of packages such as small size and medium size (or large size) (3). Shelves should have intelligent system to check and monitor the status of medicines (4). Shelves should be controlled by the condition of medicines such as humidity, temperature or other factors. (5). the structure should be adjustable and also be a durable structure. (6). the design should be able to work and integrate with the robot. Based on collected data, we have used statistic and optimization theory to provide the feasibility of demonstration shelves. After we got the number of slots, size of slot, and size of packages, we were able to discover the overall system by work space of the industrial robot, motoman HP-3.



(a)

(b)

Fig 3: An illustration of the testing and designing of the workspace (a) and (b) are a working space of motoman HP-3 which is an industrial robot

We used solid-works for testing the functions before designing the system. of the entire system is observed in a real situation and recommended by the users. Fig5 shows the design of the shelves, working area and robot function to fit our system.

V. ROBOT/AUTOMATION FOR STORING

We used Visual Basic to control the robot. The program was designed to control by scanning the barcode. When an end effector of the robot is moves to the conveyor, the conveyor would stop the function causing infrared sensor detection of the package. The robot will move the end-effector to that position. At the end of the end effector, there is a barcode scanner to detect the package. The barcode reader will scan the barcode. The information will be sent to the database to calculate an available position on the shelves. The robot's movement is controlled by Visual Basic. We have used this robot because: (1). It is a robot with low intrinsic weight; we are able to design the system based upon our requirements or area limits. (2). the robot is compact, flexible; especially its wrist and joints which are able to move and act in many positions even difficult postures (3). Because of the space, this robot requires minimal installation space.

We used forward kinematics and inverse kinematics to control the robot, following this equation; Inverse kinematic we use Denavit-Haternberg formulism, to model the manipulator. Each link is represented by the line along its joint axis and the common normal to the next joint axis. The links of the manipulator are numbered from 1 to 7. The base link is 1, and the outermost link for describing the relative arrangement among the various links. The coordinate system attached to the ith link is numbered i. More details of the model are given in [18], [19]. The 4x4 transformation matrix relates i=1 coordinate system to the I coordinate system [18]. We have decided to use an industrial robot to show as a demonstration system in the hospital site. The robot is MotoMan-HP3 which is famous in the industrial field. Visual Basic is a basic language used to control the robot.

VI. INFORMATION TECHNOLOGY AND SEQUENT

For the entire information system, we have used barcode to identify the person and to track and to monitor the drug status. After scanned and register the barcode, information would directly links to the central-data in hospital information technology services. This center will record all the procedure. It would be able to find all history. This system is designed with high security. Without permission, this system is unable accesses.

VII. SYSTEM DEMONSTRATION

Firstly, we have to demonstrate the system in drug storage. The department is a store for spare and keeps all the medicine in a controlled condition.

The robot was implemented in the mall area to demonstrate the concept of the working process. The user is the staff in this department. They participated in all the processes, from ordering the medicine to the end of process which is checking the stock. A head of the department also tested our system.

(a)

(b)

(c)

(d)

Fig 4: Implementation of the Robot Dispensing System

Following the photographs in Fig 6, picture (a) is the implemented system in the drug storage in a small area to prove the concept of a robot assisted distributing drug storage. Picture (b) shows the function of the robot and overall system which was proved in a real situation. Picture (c) shows the potential of our system that requires only one staff to work on it. Moreover, the system does not require the staff all the time. Picture (d) shows some processes of the information system which is one of the important parts of our system. We have used the online database with high security to provide an effective system. The administrator is able to remotely monitor all aspects of the system at all times.

We have implemented the system 30 days in a medium sized hospital. The place is in the drug storage which is the biggest storage in the hospital. The medicine flow is every day. The data was collected by a group of researchers, and the hospital staff. All staff has to use our system to try all of the functions.

VIII. Results and Discussion

After 30 days of implementation on site, we have collected the data below;

Traditional (Total time is 220 sec /package)

In-bound process	Time in average
Rechecking the purchase list and filling in required document	70 sec
Carrying medicine to the shelf	35 sec
Rechecking and counting stock	30 sec
Out-bound process	Time in average
Finding medicine placement	45 sec
Picking up medicine and recording stock on the recording sheet	40 sec
Carrying the medicine out	5 sec

Robot dispensing system (Totally is 170 sec/package)

In-bound process	Time in average
Filling data and packing medicine into the package	90 sec
On the conveyor (1.2 m)	2 sec
Barcode scanning	1 sec
Robot moving from conveyor to shelf (depending on the position and pose of the robot)	36 sec
Out-bound Process	Time in average
Retrieving data to pick medicine from shelf and picking up	36 sec
Moving medicine (after gripping) to conveyor and temporary box	5 sec

This table shows the result after we collected the data from Golden Jubilee Medical Center which was the medium sized hospital, in Thailand, where the prototype was tested and demonstrated. The result shows that using the traditional protocol the process takes 220 seconds per package. On the other hand, with the robot dispensing system time spent on each package is 170 seconds.

IX. Conclusion

The robot dispensing system is used for dispensing medicines. This system is designed to minimize error and improve effectiveness in drug storage by improving the process to reduce inefficiency. The results of our system show an overall reduced time wastage.

By implementation of our system to a medium sized hospital, the system is able to decrease error, to track all of processes and also decreases time for training new employee. Above all these benefits, the system would also minimize time consumption for the pharmaceutical preparation process which is shown in the results and the system is able to minimize the number of required staff. This system is also able to work all day and all night. The system in this study is a prototype which is flexible for scaling based on the needs of the hospital.

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