Advanced Medication Dispenser

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***Abstract*—Medication dispensing is an important activity that can have major implications if done improperly. Dispensing must be done in the correct time interval, at the correct user, with the correct drug and dose. We propose a smart medication dispenser that can satisfy these needs and provide a mechanism for supervision. In order to ensure that the dispensing process is error free, the concept of a new smart medication container is used. A smart medication container is "smart" as it holds the medication dispensing parameters for the drugs it contains: dispensing time and date and name. Based on this information, the actual dispensing is done.**

***Keywords*— Medication dispenser, Smart medication container, Smart House**

I. Introduction

A. Actual Medical Dispensers

A medication dispenser is a perfect system for medicine administration because it tries to eliminate, or at least minimize, the error that may appear in the process of organizing/dispensing medicine.

The problems with most of the existing medicine dispensers are that, there are semi-automatic organizers, meaning that the user must organize the medicine and set the alarms. This process is error prone, because any mistake in the process of organizing the medicine can have major consequences.

Most of the devices available are very hard to use and most of them allow the user to take an overdoses of medicine due to improper initial preparation. The user interface is contra intuitive sometimes, as the user is constrained to make various operations before the actual operation. The fact that the user must use a small alphanumeric monochrome screen and some buttons or even button combination, to accomplish complex tasks, add to the complexity of correctly setting a unit in order to dispense medicines. The existing products are not easy and fast to set up, requiring often a complex processes in order to be up and running. This process must be repeated every time a parameter, like date and time or medicine types, changes. This can be very difficult to do, especially if the person who uses the device is not able to do the process himself. This means that a supervisor must be present to make the changes every time a parameter changes. Regardless of who is setting the device, this device is error prone and the results of a small mistake can be catastrophic.

B. A Better Medical Dispenser

The medical dispenser that we propose is suitable for home use or for medical center environment due to the fact that it reduces the probability of taking a wrong drug or taking an overdose. The medicine dispenser automatically offers the user the correct dose of medicine at the correct time. The device can be monitored via an Ethernet network and offers information regarding the drugs that the user must take, or taken, via a webpage. The supervisor can verify if the user has taken the drugs and which drugs wasn't taken.

This system has a replaceable medication container module which makes the recharge with drugs process easy. It also has the possibility of using prearranged medicine containers. The drugs module contains information regarding the drugs that it contains, and the time of dispensing. The medicines are dispensed only to the correct person; the identification being done via RFID tags.

The project aims are to make an easy to use device that is able to handle complex tasks with minimum of user input, keeping the process of medicine dispensing safe. We want to create a system that manages and monitors the drugs dispensing activity in real-time. We propose the use of a smart medication container, which holds the drugs along with the information necessary for dispensing. This container can be prepared by local pharmacy, being very safe. In order to be backward compatible with current devices, the medical container supports the traditional manual arrangement of drugs, which can be error prone.

We want a device that is able to dispense the drugs in real-time; assuring that only the correct user receives the proper medication. The identification is implemented by RFID technology.

Our objectives were:

- Create a safer medical dispenser that the current models
- Implement and use a smart medical container that can hold the drugs alongside with the information needed for their dispensing, thus improving security
- Create a device that requires minimum user input to setup, if possible only replacing the medicine container

- Create a device that can be monitored remote via network interface, allowing a supervisor to access the drugs status
- Permit only the correct user to receive the medicine, by RFID identification

II. EASE OF USE THE MEDICAL DISPENSER

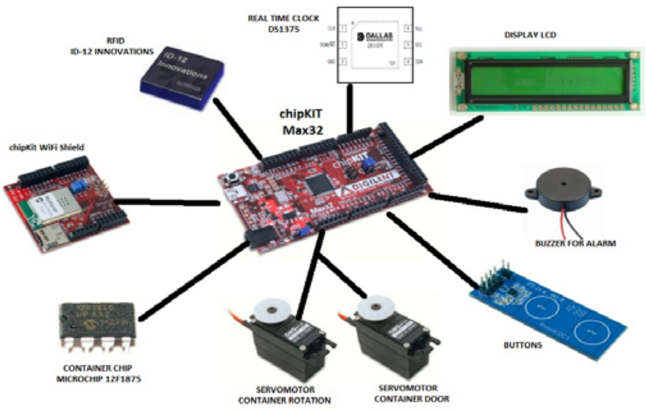


Fig.1 The medication dispenser major components

The medication dispenser is built around a Digilent ChipKit Max32 Arduino compatible board, being the central unit that connects all the other components. This platform was chosen because it combines the power and speed of a PIC32 microcontroller and the flexibility and code portability of a Arduino. This board operates at a frequency of 80 MHz, allowing the software to perform multiple tasks in the same time.

The second unit as importance is the 802.11 WIFI shield that connects to the ChipKit Max32 board, thus enabling wireless communication to the device. This creates a device that can be monitored from a local area network, and with the help of a VPN connection, the device can be accessed from any location with internet access.

The component that keeps track of time is a real time clock, and it is responsible for dispensing the drugs at the correct time. The IC chosen for this task was DS1375 from MAXIM, mainly due to its very small form factor and low power consumption.

Two servo motors ensure the actual dispensing:

- one for the rotation of the medicine container
- one for the sliding door that is at the bottom of this container.

The container is fitted with a PIC 12F1840 microcontroller responsible with the storage of the medicine list. Besides the name of the drugs, this microcontroller stores the date and time of actual dispensing. A microcontroller was chosen to act as a bridge for communication and to allow the authentication of the container. In order to keep the part count low, the internal EEPROM memory was used to store the data. This can be also achieved with other larger storing mediums; the only condition is to maintain the security, by preventing unauthorized user to modify the data stored.

A LCD module is used to display information to the user and two capacitive button modules to acquire information from the user. In the present software implementation, the buttons are not used in order to demonstrate that the user can receive the medication with almost no interaction.

An RFID module ensures that only the authorized person can take the drugs.

A buzzer is fitted in order to allow an acoustic alarm when the patient needs to receive the medication.

The components used in this project are:

- ChipKit Max32
- ChipKit WiFi Shield
- PmodCDC1 - Capacitive I/O
- GWS Servo Kit
- RTC Maxim DS1375
- RFID Reader ID-12LA (125 kHz)
- LCD DM2021-3
- PIC 12f1840
- Optical encoder used for the continuous servomotor

The system's major components are showed in Fig 1.

A. Hardware design

The Real time clock chosen for implementation is Maxim DS1375. It was chosen because it has an I2C interface and does not require a crystal. It counts: Seconds, Minutes, Hours, Day, Date, Month, and Year with Leap-Year Compensation Valid Up to 2100. This module works at 32.768kH. An external RTC was chosen in order to preserve the date and time settings while the batteries for the device are changed.

The LCD used is a SANYO DM2021 Liquid Crystal Dot Matrix Display Module with 20 characters on 2 lines. The interface used is a 4 bit of date parallel and some control signals.

The RFID chip used is ID-12 Innovations. It was chosen because it supports ASCII, Wiegand26 and Magnetic ABA Track2 data formats. The data format used in this case is ASCII because the ChipKit Max32 has a generous number of serial interfaces. This module can operate at distances up to 12+ cm, being perfect for reading a RFID card from inside the Advance Medication Dispenser housing.

The PIC 12F1840 is used as a smart and easy to interface EEPROM memory. It has 256 bytes of data EEPROM, enough to store the name and date for the 24 drugs in a container. If the container must hold more drugs, or the need to store additional information appears, this microcontroller can be changed with another one with a bigger EEPROM. The reason that a microcontroller was used, and not an EEPROM IC, is that the microcontroller can be password protected the data being more secure and tamper proof. This microcontroller communicates with the ChipKit Max32 via a serial interface.

The ChipKit WIFI shield is used to offer the project network capabilities.

The capacitive I/O buttons are used to read user input. These kinds of input devices are suitable for this implementation because the buttons can be activated even if they are closed inside the devices enclosure.

The project uses two servomotors. One normal servomotor used for the sliding door of the medicine container and one servomotor that can rotate continuous. The continuous servomotor is used in order to rotate the medicine container for the actual drug dispensing. The continuous servomotor has an optical encoder used to precisely determine the current position.

The buzzer used is a simple piezoelectric buzzer.

B. Software design

1) The PIC 12F1840 software

The software on this microcontroller acts as a bridge between the serial interface and the EEPROM internal memory, allowing storing values sent by serial interface directly in EEPROM and their retrieval. This storing method was chosen in order to increase security, this implementation allowing password protection over the data. On the EEPROM, a container start date is stored, along with 24 drug information. Each drug data contains the time difference from the last drug that must be administrated and the drug name. In order not to store the same information multiple times, the 24 drug information contains only the time difference between the last drug dispensing date and time under the form of hours and minutes. The first drug uses the container start date in order to compute the dispensing date. The container start date is used as a safety feature, meaning that if a container houses drugs with a dispensing date older that the current date, the drugs will not be dispensed. This enables the user to safely try to use an older container or even a newer container without the possibility of the wrong medication being dispensed. The algorithm maps the available EEPROM memory into portions manageable via the serial interface.

Via the serial interface, there a two possible commands:

- Read: Marked with a single character, "R", the read command is followed by:
    - A number indicating the desired position from the container, more precisely the drug number from which to read the information
    - A character, "D", indicating that the container start date and time will be read.
- Write: Marked with a single character, "W", the write command is followed by:
    - A number indicating the desired position from the container, more precisely the drug number for witch to write the information
    - A character, "D" indicating that the container start date and time will be written.

2) The ChipKit Max32

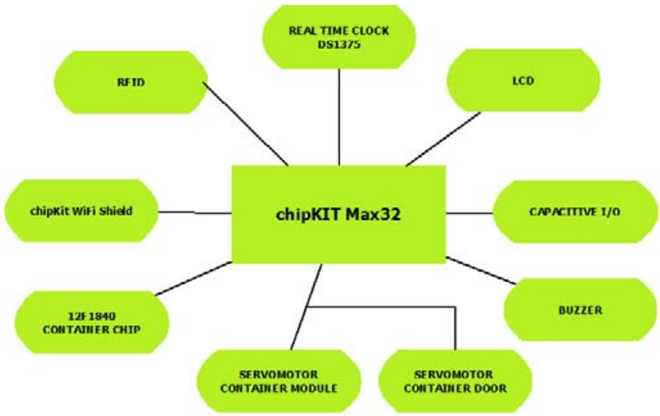


Fig.2 The medication dispenser hardware components

The program for the ChipKit MAX32 is created around the Ethernet (TCP/IP and UDP) libraries, written in such a way that any function tries to return as soon as possible, in order to avoid bottlenecks. This behavior allows a fast response to any external event, including external interrupts.

The setup part of the program handles:

- LCD module initialization
- Servomotors initialization
- WIFI module initialization
- Attaches interrupts needed for the encoder
- Loads the drug list for the first time

The main part of the program handles the process of dispensing medicine. The medicine has four possible states:

- Waiting
- Take medicine
- Taken
- Missed

The state diagram for a medication is presented in Fig. 3.

At the beginning all the drugs are in a “waiting” state. The interval that the drug can be dispensed to the user represents the “take medication” state. After that, depending on the user actions the drug changes its state into “medication taken” if the user authenticated with the system or else “medication missed”.

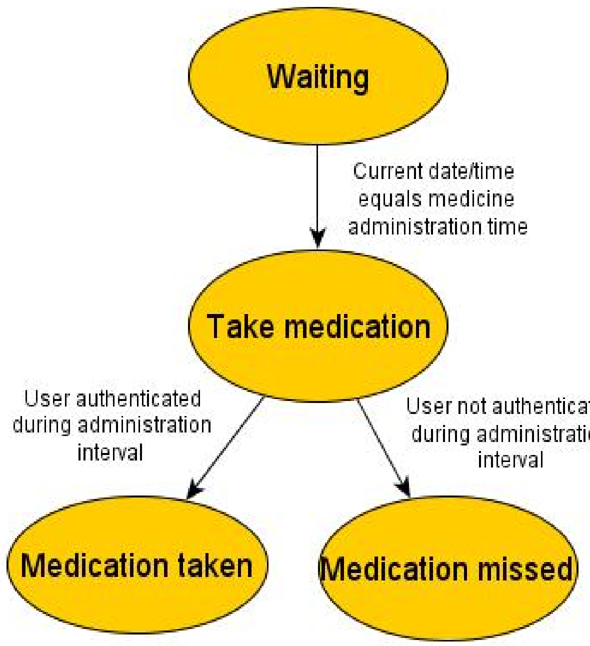


Fig.3. The medication state diagram

After the medicine list is loaded from the PIC 12F1840 microcontroller, the list is parsed in order to find a medicine that must be administrated. This is done by comparing the administration date/time of the medicine with the current date supplied by the RTC module. Initial all the drugs are in “WAITING” state. As soon as “a ready to dispense” medicine is found, the medicine gets updated into the “TAKE MEDICINE” state. A timer is started, in order to allow the person to receive the medicine only in the correct time interval. The buzzer alerts the user that he must take the medicine and a message is shown on the LCD screen. As long as the administration interval is not exceeded, the system waits for the user to authenticate with the personal RFID card. If the user presets the correct RFID card within the valid time interval, the medicine is dispensed, the user receiving the drugs. After this the timer and buzzer are stopped and a message is showed on the LCD screen. The medicine state updated to “TAKEN”. If the time interval has been exceeded without a valid authenticated user, the medicine is marked as “MISSED” and the buzzer and timer are stopped. A message is left on the LCD screen in order to inform the user that a medicine has been missed.

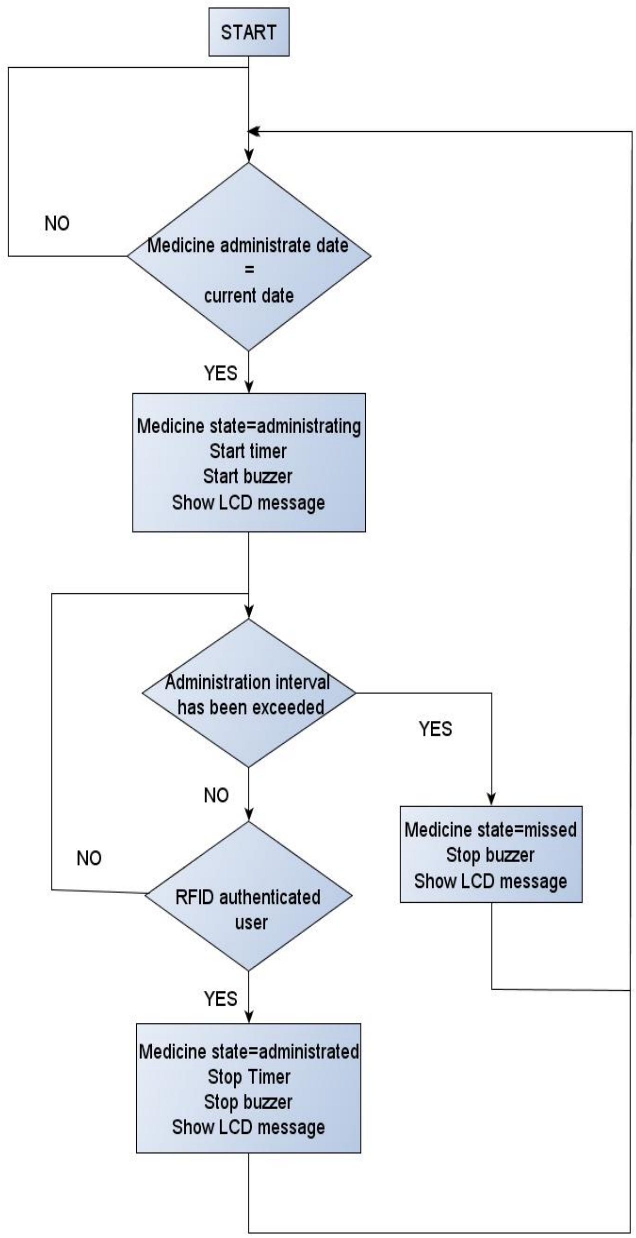


Fig. 4. The medication dispenser activity diagram

This behavior is presented in Fig. 4 in the medication dispenser activity diagram.

The Ethernet library creates a web server, which allows a remote person to connect to the device and monitor the medication dispensing activity. The supervisor can access the devices web page from any location, via internet. The supervisor must be authenticated in order to be able to see the medicine dispensing related information (Fig. 5).

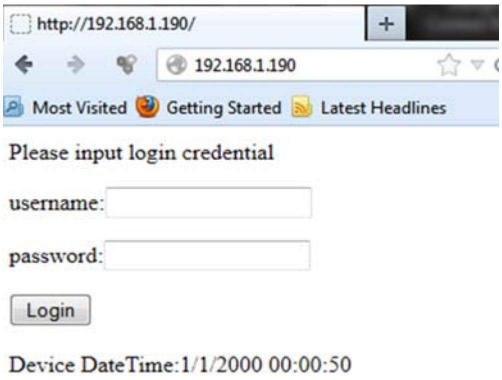
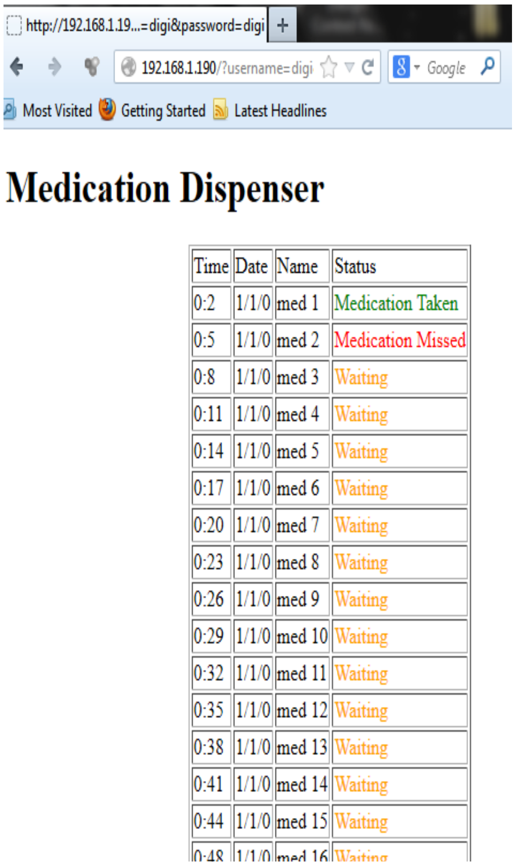


Fig. 5. The medication webserver User Interface (Login)

The login information is stored on the device in the current implementation. Also the current implementation is created for a single user.



Time	Date	Name	Status
0:2	1/1/0	med 1	Medication Taken
0:5	1/1/0	med 2	Medication Missed
0:8	1/1/0	med 3	Waiting
0:11	1/1/0	med 4	Waiting
0:14	1/1/0	med 5	Waiting
0:17	1/1/0	med 6	Waiting
0:20	1/1/0	med 7	Waiting
0:23	1/1/0	med 8	Waiting
0:26	1/1/0	med 9	Waiting
0:29	1/1/0	med 10	Waiting
0:32	1/1/0	med 11	Waiting
0:35	1/1/0	med 12	Waiting
0:38	1/1/0	med 13	Waiting
0:41	1/1/0	med 14	Waiting
0:44	1/1/0	med 15	Waiting
0:48	1/1/0	med 16	Waiting

Fig. 6. The medication webserver User Interface

C. Medication Container

The medical container is designed in order to create a safe and reusable medical storing device. It is safe because only the medical dispenser can open it and it is reusable because it can be filled with different drugs and the stored information updated.

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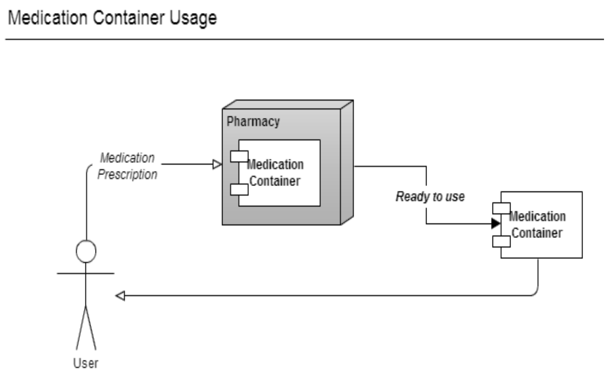

Fig. 7. The medication dispenser container life cycle

This container (Fig. 8) is designed to avoid medication overdoses and accidents. The container is supposed to be obtained from the pharmacy based on a prescription.

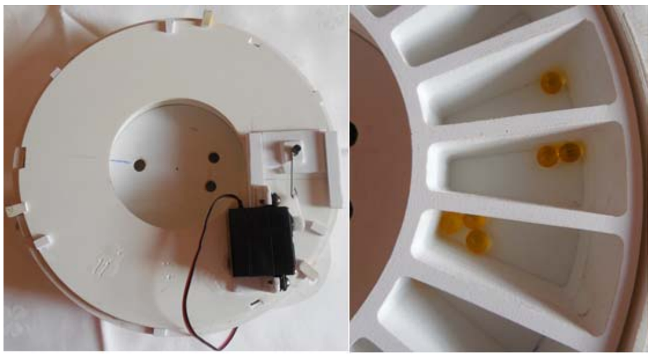

Fig. 8. The medication dispenser container

D. The User Interface

The medical dispenser has a simple yet powerful user interface. Since it is designed with simplicity in mind, the user interface components are:

- The LCD screen
- The LED’s
- The Buzzer
- The RFID reader
- The capacitive touch buttons (are not used in the current implementation)

The LCD screen is used to display the current time and date. Along with this information, the take medication and medication lost event are displayed.

The LED's, one green and one red provide a quick way (Fig. 9) for the user to know if he must take the medication (green LED) or he has missed a dose of the medication (red LED). The green LED is ON during the interval that the user can take the medicine. In order for the user to receive the medication, he must authenticate via RFID. The red LED is ON in the interval that the user has missed a dose of the medicine and the next dose of the medicine. It stays ON for that period in order to inform the user that something is WRONG, more precisely he has missed a dose of medicine.

Fig. 9 The medication User Interface

Another element is the buzzer, which announces acoustically the moment that a user can receive its medicine. The buzzer stays ON as long as the user can take its medicine, in order to force him to take the medicine as soon as possible.

The RFID is considered as a user interface element since the user authenticates using this device and a RFID tag. This authentication is used since it requires less user action and it is reliable. The most secure implementation will use RFID microchip implants that ensure that the person receiving the medicines is the correct one.

E. Developing environment

For the programming of the dispenser, the developing environment used was a Widows 8 Enterprise PC. The PIC 12F1840 was programmed with the PCWHD compiler & IDE and the program was transferred to the PIC with the OLIMEX PIC-PG1 serial programmer. The ChipKit MAX32 was programmed with the MPIDE environment.

CONCLUSIONS

The project (Fig. 10) has been implemented and meets all the specification goals. This project offers a complex assistance and medicine dispensing system. Due to the security checks used, RFID identification, the system is able to avoid potential critical medicine administration errors, and to ensure that the medication has been taken.

This product offers more features than other related products, like patient supervision via internet and almost instant setup.

The system is open to extension and integration with the smart house and a wide range of sensors.

Fig. 10. The medication dispenser

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