International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

# Evolution of Smart Pillbox: History and Reasons for a Need to Design a Smart Pillbox

Richard Sather III, AbdulAziz Abutunis, Gireesh Menta, Thomas Zurales, Dale Dowling, Nabiha Imtiaz, Arshia Khan*
Department of Computer Science University of Minnesota, Duluth, MN, United States

***Abstract—*** *There are a number of smart pillboxes available for medication management. The need for these types of pillboxes has slowly grown in the last decade. This paper will explore the history behind the need for a smart pillbox and the evolution of the mechanical design as well as the electronic control design behind them. The first part of the paper will discuss the history of medication management and the need for pillboxes. The second part will examine some of the mechanical design features of these boxes, and the third part will look at the electronic controls. Finally the paper will discuss the various pillboxes currently on the market and their usefulness.*

## I. INTRODUCTION

In 2015, the world population for people aged 65 or older reached 8.5% of the total population [1]. The older populations in more developed countries are expected to continue to grow in size. To further add, the United States healthcare system will have to worry about the rapidly increasing number of elderly people due to the baby boomer generation. As the United States' older population continues to grow, so do the number of medications taken among older adults. The elderly often have chronic health conditions which require essential medications. Between 1988 and 2010, the median number of prescription medications used among adults aged 65 or older doubled from 2 to 4, and the percentage taking greater than 5 medications increased from 12.8% to 39.0% [2]. Dealing with multiple medications can pose as a difficult challenge for an individual. Currently, a big concern in healthcare is the issue of medication errors. The most common causes of medication errors include poor communication amongst doctors, poor communication between patients and their doctors, and drug names that sound and look alike [3]. Taking too many, or incorrect medications can lead to potentially fatal consequences.

Adverse drug events (ADEs) lead to more than 3.5 million physician office visits and 1 million emergency department visits annually. Additionally, preventable medication errors impact more than 2 million patients and cost almost $21 billion each year across all care settings [4].

Furthermore, 7,000 to 9,000 people die due to medication error alone in the United States [5]. There is some evidence that suggests that polypharmacy in older adults is associated with negative health outcomes such as decreased functional and cognitive health status, increased risk of falls, adverse drug events, hospitalizations, and mortality [6]. The decreasing frequency of pill bottle reviews and poor patient education may threaten patient safety [4, 6]. As a result, methods for developing a safe strategy to manage a larger medication list is of substantial concern.

Techniques to promote medication management is an emerging area of healthcare research. The goal is to create a safe and effective method for helping individuals manage their lengthy or confusing medication list. Medication management is accomplished when patients are able to take the correct medication and dosage to help them avoid possibly dangerous medication administration. The concept of medication adherence is crucial when developing a method to help remind people when to take their pills. Failure of adherence in patients can lead to worsening of a current disease, increased healthcare costs, and possibly death. Non-adherence can occur when the medication regimen is extensive, which could include improper timing of drug administration or administration of medications at frequent or unusual times throughout the day [7]. In addition, people may have difficulty reading and understanding the instructions on the labeled bottle. A single method alone cannot solely solve the issue over medication adherence. Some people may enjoy simple reminders ,like alarms, to help take their medications on time.

However, patients with mild cognitive impairment or dementia may need extra assistance. Studies have shown that the use of compliance aids, such as pillboxes, and proper motivation and support is shown to increase medication adherence [7]. It is important to keep in mind that the utilization of a compliance aid should include a multidisciplinary approach to support all people taking medications.

Drug reminding packaging, including those of pillbox organizers, are widely used both at home and in healthcare settings. Compared to patient counseling, education, and motivation [8], drug remiding packages or pillboxes are simple options that require few resources from the patient and their provider [9]. A systematic review conducted by Boeni et al., (2014) looked at 30 studies that utilized drug reminder packaging and their effectiveness in promoting drug adherence. Results had shown that several of these studies had statistically significant and relevant results for drug adherence and clinical outcomes with drug reminder packaging [9]. On the contrary, a research study conducted by Huang et al., (2000) found that the use of blister packs, but not pill organizers, improved adherence by pill counts for those with lower drug adherence [10]. The emergence of newly designed robotic pillboxes and organizers may provide a unique perspective in taking medications. The introduction of a



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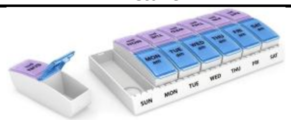
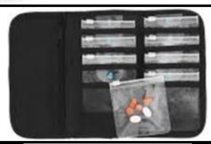
International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

robotic component for pillboxes can alleviate the burden of having to organize the pills either by a pharmacy or yourself. This paper will investigate various types of pillboxes currently available on the market. We will also discuss the mechanical and electrical design development of the pillbox that led from the standard unintelligent pillbox to more advanced robotic pillbox designs. Safety considerations and recommendations for future pillbox designs will also be considered to understand the approach in medication management and adherence.

## II. History of Pillboxes

A pillbox, also known as a pill organizer or pill container, is a multi-compartment compliance device designed to schedule appropriate medication distributions for people. The first pillbox was patented on August 4, 1964 by David Wagner. It included both a circular and rectangular design. Similar to today, the standard pillbox has square-shaped compartments that divide the box into seven compartments for each day of the week. More intricate pillboxes extend their dimensions to include various times throughout the day. Medication organizers have been utilized in healthcare settings and personal home environments to avoid potential medication errors. It also has the ability to organize a doctor's recommended dosings amongst several medications. The pillbox allows a patient to remember whether or not they have taken their medication at a particular time of the day based on if the pills remain in, or are missing from a certain compartment. Electronic pillboxes have recently been developed to further act as memory aids in order to promote patient safety. These enhanced forms of pillboxes can alert a person when it is time to take their prescription or over-the-counter medications, food supplements, or vitamins.

TABLE 1: Overview of Unintelligent Pillboxes Designs

| Category | Description | Picture |
|---|---|---|
| Basic pillbox | The most simple pillbox form. Labels are generally large, making it easy for those with vision problems. Opening and closing the compartments is easy. |  |
| Pillbox for people with arthritis | This pillbox has buttons to push to open the lids of the compartments. It helps with people who suffer from arthralgia, such as osteoarthritis or Rheumatoid arthritis. Labels are large to help with reading. |  |
| Travel pill organizer | Travel pill organizers provide an alternative way to manage medications. It goes away from conventional boxed compartments to a more pouch-like appearance. It is easy for storage in a backpack or suitcase. |  |
| Emergency pillbox | These are small canisters that can hold one type of medication for emergency use. The medication, for example, may include nitroglycerin for sudden, onset chest pain. |  |
| Pillbox organizer with alarm | Pillbox organizers may now include the use of an alarm. The user is able to see a clock face and set an appropriate alarm for when it is time to take their medications. |  |
| Pre-packaged pharmacy pill tray / container | Pharmacy medication trays are another category of pill dispensers. A pharmacy may offer pre-packaged medication which can be loaded into a tray. The tray has the ability to dispense medication on time, provide reminders, track medication adherence, and notify caregivers if medications are not being taken. |  |
| Circular pillbox | This pillbox goes away from the traditional rectangular compartments and incorporates a circular, rotating wheel. The shape gives another option for people. Operating mechanics are similar to the basic pillbox. |  |
| Robot pill organizer / dispensers | These emerging pill organizers make filling medications easier. Robot pill organizers have the capability to automatically dispense medications. They are designed to be relatively simple to operate. They can also handle tasks such as organizing all medications and distributing the pills at appropriate times. | Refer to Table 4 below |

The electronic pillboxes can even be synced through the internet to a person's local medical facility to provide an additional source of monitoring. There are three types of pillbox designs that are explored throughout this paper. These include unintelligent pillbox designs (Table 1), self-filling pillbox designs (Table 2), and robotic pill organizer / dispenser designs (Table 4). The mechanical design of the pillbox will be considered with regards to the transition from the standard unintelligent pillboxes to the more intricate pillbox designs.

## III. Mechanical Design Evolution

The structural and mechanical designs of smart pillbox dispensers can be as simple as rectangular or circular containers with compartments into which the user loads the individual doses of drugs and takes them manually when an on-board alarm goes off, or a light indicator turns on when it is time to take the medications [11, 12]. The complexity of the designs increase as the automation level increases. In the literature, to provide a meaningful description of how the mechanical mechanisms of pill box dispensers work, it is essential to relate it to the accompanying sensing, managing, and control systems.

Some of the earliest designs of smart pillbox dispensers appeared in the 1980s developed to reduce medication errors and assist pharmacy and nursing staff [13]. In 1984, Barker et al. proposed the McLaughlin dispensing system, a rectangular container with multiple drawers to store the pills [14]. A locking system, programmable magnetic card, and pharmacy computer were used to automate the dispenser. At the dosing time, a particular drawer unlocks automatically allowing the caregiver to remove the dose and administer to the patient. The system also alerts the user by turning on a light when the pill drawer is unlocked. In 1994, Klien et al. designed a dispensing system where pills are stored in calibrated medication canisters [15]. The location of each canister is identified by a number. When it is time to dispense pills, a microcomputer receives a signal and a specific canister dispenses a pill into a strip packing device where the medicine is labeled and hermetically sealed.

In 1999, Wan et al. proposed a smart pillbox dispenser called the “Magic Medicine Cabinet”, an interactive and smart appliance that uses face recognition technology to identify the approaching person and responds with pre-programmed services [16]. The medicines in the cabinet are labeled with RFID-based smart labels which were used to identify the pills. The cabinet had an embedded computer, internet connectivity, monitors to track the vitals of the patients (such as heart rate, cholesterol, blood pressure), and the ability to provide auditory output to the user. In 2004, Fishkin et al. developed a similar medicine cabinet with a lighter weight version and used RFID tagged pill bottles that are placed on a monitoring pad with embedded RFID tag reader and a scale [17]. The change in weight was recorded via scale and was used to monitor the amount of medication taken.

Hayes et al. [11] developed a pillbox called MedTracker that has seven side-by-side compartments for the seven days of the week. Each compartment was fitted with a plunger inserted through a plastic bushing that would be depressed by the lid when opened, and would contact a switch under the box on closure. When the sub compartment lid on the pillbox was opened, the plunger releases the switch and sending a signal to indicate the door is opened.

The status of each lid (identified by a door id) is monitored once every second and if any change in status is sensed, it is marked and saved to a circular RAM buffer in the 18LF252 PIC microcontroller for later processing. Each timestamp is stored as 3-byte values and 256 events can be stored on the on-board memory.

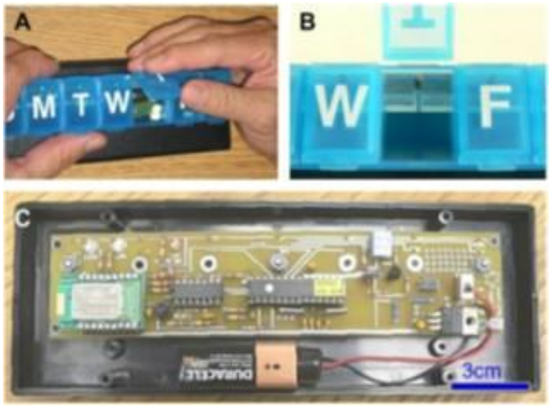



Fig. 1. The MedTracker Device. A) Outside of the device: B) Closeup of the plunger that activates the switch to record door openings; C) Internals

Tsai et al. designed a pill dispenser containing a rectangular base with several sockets that fit the conventional drug containers [12]. Each socket has a switch at its base that is closed when a container is plugged into the socket. An RFID reader is placed inside the base to read the tags on the containers and identify the pills. To use the dispenser, the user plugs the medication schedule specifications (MSS) into the on-board memory card reader of the dispenser. When new pill containers are placed into the sockets, the state of the switch for the socket changes from open to close, which commands the RFID reader inside the base to read the tag on the containers.


Fig. 2. Smart Dispenser developed by Tsai et al.

The dispenser gathers the details of the pills and the schedule from the inserted MSS disk. The container is then



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locked inside the socket. When the time for medication comes, a reminder starts and the pillbox lights up an indicator around the specified socket and unlocks the due medication container, so it is ready for removal.

Abbey et al. [18] designed a pillbox with rectangular UV resistant transparent plastic chambers organized in seven columns and four rows corresponding to the days in a week and number of doses per day. The floor of each chamber is curve-shaped to allow the pills to gather in an indent at the bottom of the chamber. An LED light is placed inside each chamber and a sensitive ambient light sensor is attached just under the indent at the bottom of the chamber. To use the dispenser, the patient or caregiver sorts the medicines based on the dosage, and loads into the chambers accordingly. At the scheduled time, the LED light in the corresponding chamber starts to glow and the light sensor begins to monitor the light intensity to determine if the pills have been collected or not. The light sensor outputs a square wave signal proportional to the incident light intensity. An on-board arduino based platform analyzes the frequency and notifies the mobile app via Wi-Fi connectivity. An alarm goes off on the mobile application until the patient takes the pills or selects the postpone option. The mobile application also offers multiple options including a calendar-like interface that serves as a supervisory schedule.

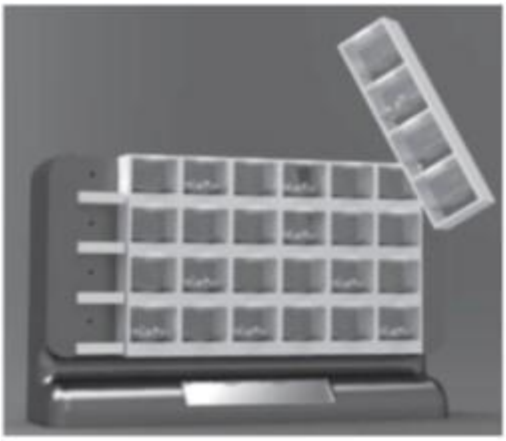

Fig. 3. Pillbox developed by Abbey et al.

Minaam et al. [19] employed a canny pillbox design that is comprised of four major parts: a pill storage, a pill hatch, a pill chamber, and an exit pipe. Pill storage simply consists of multiple compartments in the form of hollow pillars along the length of cylindrical tubes where pills are contained on zippers. To dispense the pills, holes on all the parts need to align. For example, during the refilling or storage phase, the pill compartments in the storage chamber are not aligned with the opening of the pill hatch and prevent pills from exiting the storage. The other functions of the pill box are based on the alignment of the openings in these four parts. To drop the pills from storage into corresponding compartments, a servo is used. To ensure only one pill is dispensed, the chambers are made to fit only one vertically positioned pill. In the pill dispenser unit, two Arduino-controlled servos are used: one located under the lid attached to the storage cylinder and another to control the intermediate piece. The pillbox used the ESP package for the WiFi connectivity and a mobile application to interact with the patient or caregiver.

Chen et al. [20] proposed a simple pillbox with three parts: base, storage and lid. The base houses a stepping motor, power socket and other wiring. The storage is a rotary disc or turn table with 8 storage compartments to store the pills. The lid is a dust cover and is fitted with an OLED display and has one sector-like opening that serves as a taking mouth. The lid and base are embedded with magnets that hold them together in place. The design uses a reed tube sensor to identify the number of the rotary compartment, a stepping motor to control the rotation of specific compartment to the opening and a STM32 series single-chip microcomputer to control the sensor to sense the approaching human body. OLED display and buzzer sounds are used to notify the users. At the medication time, an alarm goes off to alert the user and a sensor is used to locate the needed compartment number. The stepper motor rotates the identified compartment so it matches with the fixed opening and allows the user to access the pills. If the user does not collect the medicine, the pillbox continues to play buzzer sounds for upto one hour when the user is in close proximity. The author also developed a mobile application to program the pillbox.

Huang et al. designed a pillbox based on the dispensing mechanism similar to that of vending machines [21]. The pillbox consists of a spring with a base plank underneath. A servo motor is used to rotate the spring, which pushes the pill packages forward. When the package is pushed past the plank, it is dropped at the entrance. Infrared sensors installed at the entrance detects the drug being delivered and records to SQL server via the wireless serial port. When it is time to take medication, an alarm goes off and continues to do so until the medication is picked up. The time of delivery and pickup are recorded and notifies the caregivers or families via Skype.

Pak et al. proposed a smart pillbox that is highly scalable and remotely manageable [22]. The medicines for each patient are stored in a medication cartridge and the cartridge is placed in a Medication dispenser tray (MDT). The MDTs are easily attachable together and the proposed pillbox can extend upto six MDTs maximum. The pillbox is remotely managed by medical staff workers or caregivers where the information of the medicines and schedules are entered or updated for each patient. The dispenser is operated on the WinCE platform, uses the MCU to control all system functions, a LCD screen to display medication information and set schedule, MDT to store & dispense the medication, an alarm system to alert the user, IR sensors to track the number of pills, RTM to record the time and date information, and RS232 serial communication module. When it is time to take the medicine, the pillbox alarm goes off to alert the patient, the user presses the dispense button and the predetermined medications are dispensed.



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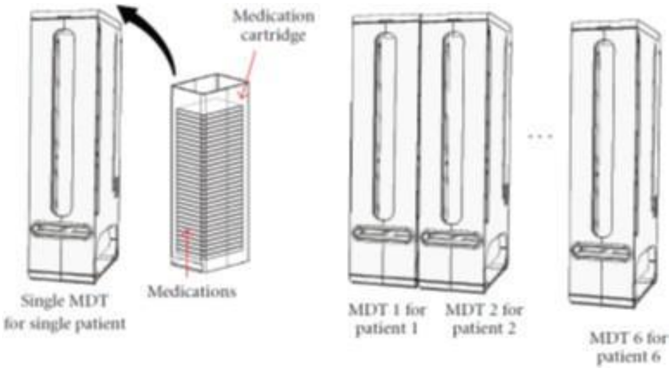


Fig. 4. Smart Medication dispenser with multiple MDTs

Antoun and Kassem [23] developed a pillbox using parallel rotary wheels each with seven sectorial compartments for pill storage. Each rotary wheel is controlled separately by axially- coupled servo motors. The medication management is set via an Arduino user interface. When it is time to take the pills, a cell phone which is connected to the Arduino through Bluetooth, starts sending commands to the designated servo motor. Based on the user approval, the servo motor rotates the attached wheel by a specific angle and dispenses the pills through an opening at the bottom until that compartment is empty. The system uses a cell phone alarm to notify the user. And the unit can be expanded to include several rotary wheels.

Oniga et al. designed Advanced Medication Dispenser built around a Digilent ChipKit Max 32,

802.11 WIFI shield for wireless communication, DS1375 from MAXIX as IC, and PIC microcontroller to store the medicine information [24]. Using RTC, the date and time of dispensing is stored. An RFID was used for user identification. An LCD module with two capacitive buttons on the dispenser is used as an interface for the user. The pillbox contains multiple sections with a sliding door at the bottom of the container. Two servo motors: one for rotating the medicine container and another one for opening the sliding door are used to ensure the actual dispensing. When it is time to take the pills, the buzzer goes off with a notification on the LCD screen. The user identifies via RFID tag, stops the buzzer and the pills will be delivered.

The Weekly Electronics Pills Dispenser with Circular Containers is an intelligent pillbox developed by Farcas et al [25]. It has seven circular containers placed in a tube with an opening at the bottom. Each container is partitioned into four sections (number of dosages per day) where pills are stored. A 2-Line LCD is used to manually enter the schedules for the pills. When it is time for medication, stepper motors controlled by a microcontroller rotates the containers until the certain section faces down. When the right section is turned towards the bottom of the tube, the pills fall on to a plate placed under the tube. An alarm goes off to alert the user.

Othman et al. developed a smart pillbox using combination of infrared sensors, Arduiono microcontrollers and alarm systems [26]. The construction of the pill dispenser includes three compartments to store three different types of pills. To use the pillbox, the user enters the time and the amount of pills in slot selection on an LCD screen with several buttons. When it is time to take the medicine, an alarm goes off and notifies the user via popup notification on the smart phone. Then the user presses a button on the pillbox, a servo motor opens the gate of one of the three containers, and the vibration motor vibrates the pill storage compartment until the pills are dispensed to a drawer through a pipeline. An IR sensor tracks the number of pills falling out and stops the vibrator when the required number of pills are dispensed. A Real Time Clock (RTC) module provides information on time and date. All the inputs are outputs are connected to the Arduino Mega 2560 microcontroller. The Raspberry Pi B+ and vibration motor are indirectly connected to Arduino through the relay module.

A similar technique of notifying users via SMS was employed by Chawla et al [27]. This design consists of three sub-systems with each consisting of a pill container, 3D printed cone and two wooden dowels. Three pill containers store three different types of pills and are located at the bottom of each sub-system. The textured 3D printed cones are designed in such a way that a single pill is precisely caught each time regardless of the radius and shape of the pill. Using a LCD display, users enter the medication schedules and information. When the medication time arrives, an Android application sends a Bluetooth signal via HC-06 module to the Arduino microcontroller. A servo motor connected to the cone rotates the cone, catches a single pill and using two connected dowels applies force to dislocate the pill from the cone and dispense it.

The e-pill MedSmart is a commercially available automatic pill dispenser that uses a turntable with labeled compartments to store the pills [28]. It can dispense upto six dosages per day. It employs an alarm system, LED lights, and connectivity via phone to alert the users. It uses a locking system that prevents users from accessing wrong medications. When it is time to take the medicine, the dispenser sets-off the alarm and turns on the LED light. If the medication is not picked up within 60 minutes, it sends text messages or an email notification to caregivers. A display on the dispenser acts as an interface to show the time, day, inventory of pills or to set the schedule time or select the alarm type etc.

Fig. 5. e-Pill Med Smart automatic pill dispenser

TABLE 2: Self-filling Pillboxes

| Product | Description | Picture |
|---|---|---|
| MedMinder | This pillbox is able to handle solid forms of medications. It must be stored at room temperature. The mechanism has large individual compartments. It has a flashing light to indicate which compartment to open. It has its own built in cellular connectivity. |  |
| Philips | This pillbox is able to handle solid forms of medications. It must be stored at room temperature. The design is very simple. There is a single button to press that dispenses the medication.<br>One limitation is that this pillbox needs a landline. |  |
| GMS | This pillbox is able to handle solid forms of medications. It must be stored at room temperature. The design requires a simple tilt of the circular pill box to dispense the medication when it beeps. |  |
| MedReady | This pillbox is able to handle solid forms of medications. It must be stored at room temperature. This system relies on a circular pill wheel concept. It has its own built in cellular connectivity. |  |
| Tabsafe | This pillbox is able to handle solid forms of medications. It must be stored at room temperature. This machine is not able to handle fluid-filled gel tablets. |  |
| Compumed | This pillbox is able to handle solid forms of medications. It must be stored at room temperature. It requires internet connectivity to work well. |  |

TABLE 3: Storage of Self-filling Pillboxes

| Product | Doses / Day | Number of Compartments | Pills / Compartment | Total Pill Capacity |
|---|---|---|---|---|
| MedMinder | 4 | 28 | 12 | 336 |
| Philips | 6 | 60 | 30 | 1800 |
| GMS | 6 | 28 | 14 | 392 |
| MedReady | 4 | 28 | 12 | 336 |
| Tabsafe | 4 | 4x16 | 7 | 448 |
| Compumed | 4 | 28 | 15 | 420 |

## IV. SMART PILLBOX

Smart pillboxes have simplified the way in which medication filling and distribution is handled. Pill robots have been designed to promote drug adherence. Caregivers do not need to manually sort out an elderly person's numerous medications. These robots can take in several types of medications and adjust the schedule accordingly. Each robot has a simple user interface that allows people to handle the

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

device either through a phone application or directly on its screen. The machines can then dispense medications based on the times and quantities reported on its initial set-up. Different types of Robot pill organizers and dispensers are shown in Table 4 below.

TABLE 4: Robotic Pill Organizer / DIspensers

| Product | Description | Picture |
|---|---|---|
| Hero | Automatic pill dispensers organize the pills to take when you need them. They also have the capability to prevent you from taking the wrong pills at the wrong time. The machine does all of the pill organizing itself. An additional feature allows caregivers to make changes to medication regimen from any location. Medication is loaded into the machine and is guided by the user interface on the product itself. After choosing a particular medication to fill, a door located on the system opens to pour as many pills inside as you wish. The user interface then proceeds to move on to a repetitive process to fill each type of medication to be stored in the system. Some limitations occur due to its internal technology. These automatic pill dispensers do not have the ability to handle half pills. A new capsule of a particular dosage must be placed into the system. The machine cannot also handle chewables or liquid-filled gel capsules. |  |
| MedaCube | |  |
| Livi | |  |

TABLE 5: Storage of Robotic Pill Organizer / DIspensers

| Product | Number of Compartments | Pills / Compartment | Total Pill Capacity |
|---|---|---|---|
| Hero | 10 | 80 | 800 |
| MedaCube (standard arrangement)* | 8 | 160 | 1280 |
| Livi | 15 | 160 | 2400 |

*MedaCube consists of 8 slots that can be customized to fit 12, 14, or 16 containers

## V. ELECTRICAL DESIGN EVOLUTION

In situations where there is a need for a wider variety of dispensing schedules, types, or functionality, it may be prudent to use highly reprogrammable embedded devices, such as Dragonboard, Raspberry Pi, and Arduino, which often include onboard operating system user interfaces. These allow for quick prototyping of new ideas, are very well documented, and have the computing power to perform a wider range of tasks than other, more cost effective embedded devices. With the advent of the Internet of Things, providing connectivity to the internet, as well as providing greater security standards for electronic devices, collecting and analyzing data, and providing regular feedback to the user are becoming increasingly important from the perspective both of consumers and of care providers.

## VI. SAFETY CONSIDERATIONS

The safety features in robotic pill organizers/dispensers require a high degree of precision and accuracy in order to prevent accidental mismedication. There is an inherent level of trust given to automatic systems to produce correct results, so there is a risk of medications not being verified by users before consumption. While the control systems of many of the robotic pill organizers listed above are proprietary, there are several common safety measures which must be observed in order to ensure proper operation. The safety measures which must be common between any such pillbox are: accuracy of timing, accuracy of selection, and assurance of delivery. Each of these controls will be discussed in finer detail, and possible implementations will be discussed.

Accuracy of timing means that pills will be dispensed at the correct times of day, and at the correct intervals. To ensure this, the robotic pillboxes listed above use an internet connection to check the current time, ensuring pills are dispensed when expected. Using an internet connection also mitigates the risks posed by edge cases such as daylight savings time, ensuring the pillbox always knows the correct time of day. Ensuring accuracy of timing also requires handling failure conditions such as power outages. In the event of a power failure, the user should at the very least be warned of any missed scheduled medications, or better yet, a battery backup could be used to allow the device to continue functioning uninterrupted until power is restored. Further redundancy can be added by including a real time clock module to the device which would keep track of the current time, even when the device is powered off.

In order to ensure accuracy of selection, any robotic pillbox must take steps to ensure that it knows what medications are being output. This means ensuring that the pillbox is able to recognize conditions which may affect accuracy of selection, and take steps to prevent incorrect outputs. In the case of the MedaCube, a tilt sensor is included to recognize if the pillbox is rotated or dropped. This knowledge allows the pillbox to recognize if an event which would compromise accuracy of selection has taken place, and to take steps to prevent incorrect outputs. The pillbox automatically locks and will not dispense pills until an authorized caregiver verifies no pills were moved, or corrects any that were moved. This is just one of many safety features built into robotic pill boxes. There are other ways pills could be moved out of place however, and in order to ensure accuracy of selection, any risk of contamination must be mitigated.

Assurance of delivery is one of the primary benefits of smart and robotic pillboxes. The Medecube, Hero and Livi all have the ability to alert either the user or a defined caregiver if dispensed pills were not taken by the user in a reasonable amount of time. This assurance of delivery has led to significant increases in consistency for users of smart pillboxes compared to users of older styles [29]. The family and caregivers of the user of a smart pillbox also benefit from having access to data about when medications were taken, and alerts if they are not.

## VII. DISCUSSION

Discussion of the usefulness of the pillboxes, pros and cons etc. Both self-filling pillboxes and robotic pill organizers / dispensers are frequently used in everyday life for medication management. The goal of the pillbox design is to organize pills, in hopes to eliminate error prone aspects in managing medication regimens. Different pillboxes can be used in different life situations. A particular pillbox may have beneficial use for those with physical impairments, such as hearing, vision, arthritis, or mobile limitations, or cognitive impairments, like that of dementia. A study conducted by Schwartz (2016) found that users reported selecting pillboxes based on their needs in addition to the demands of their medication regimen [30]. In addition to selecting an appropriate pillbox, it is important to consider medication compliance. In a study by Mallion et al., (1996), compliance data was evaluated amongst 501 patients for those afflicted by mild to moderate hypertension. Observations of the research had shown that doses were forgotten and delayed more often during weekends than weekdays [31]. In addition, the greatest number of delayed doses occurred in patients under 60 years of age [30]. Pillboxes and their use for drug adherence have also been studied for life-threatening diseases such as HIV. Kalichman et al., (2005) identified that pillbox users indicated a feeling that they benefited from using a pillbox. It was shown that pillbox users were significantly more likely to have undetectable viral load and less likely to to miss their daily medications [32].

Smart pillboxes are becoming increasingly valued in healthcare and home settings. Choi (2019) discovered that primary care patients who reported missing a dose by accident were 2.4 times as likely to want to use a smart pillbox, while those with heart disease were about 4 times as likely to want to use a smart pillbox [33]. Some scientists have developed their own smart pillbox that enables caregivers to determine the pill amount and timing. Minaam and Abd-ELfattah (2018) developed their own medicine reminder and monitoring system to help older people take care of their medication. Their personal design was able to diminish the proportion that patients miss and defer taking medication [34]. They have also added the feature to include usability through networking locally or over the internet [34]. Besides having the ability to connect over the internet, smart pillboxes are currently being designed to include a smartphone application.

Botella et al., (2013) developed with his team an mobile application to accompany an individual's pillbox [35]. The application was orientated to larger screens and included adequate font size, understandable messaging system, good contrast amongst various interfaces, and minimalist design to limit elderly confusion. 24 subjects participated, averaging an age of 72.16 years. All users were satisfied with the design of the alerts. The mobile application helped patients with medication compliance. In addition, the application was rated a 8.63 over a 10 point scale in overall satisfaction with the application [35].

With the large variety of pillboxes on the market, it can be difficult to find the appropriate one for a person's lifestyle. More advanced pillbox models currently available, like Hero, MedaCube, and Livi, are designed to eliminate the repetitive task of sorting many pills into individual pull compartments for each week. The ability to sort medications at ease and dispensing them to people at designated times of the day may help reduce caregiver burden. Caregiver burden is a big issue in geriatric and disability care. The caregiver has the risk of becoming ill themselves, including insomnia and depression, and are less likely to engage regularly in self-care [36].

Having a smart pillbox can make a substantial impact for caregivers who are currently filling pill boxes every week. It will eliminate having to worry about medication mix-ups and also save personal time for the caregiver. Another concern about pillboxes is the ability to read its labeling. A normal process of aging is presbyopia, an age-related loss of the eye's ability to focus on near objects. Some of the standard compartment pillboxes have smaller letter printing, which may make it difficult for people to read with vision impairment.



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The MedaCube accommodates this by using a large green button to press to dispense the medication. Some elderly people also have to worry about tremors or other fine motor control issues. Pillboxes such as MedMinder and Philips have large, easy to handle components. In addition, MedaCube has a larger touchscreen to assist with fine motor control issues.

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