RAPID - Reliable Autonomous PIll Dispenser

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1 INTRODUCTION

In a society with an increasing elder population[Hobbs 2001] combined with traditional non-reliable forms of medicine intake control solutions, our society is faced with the growing problem of wrong medicine administration by frequent users that rely on traditional methods.

The Italian average for medicine consumption is 1.5 pills a day, with this value climbing to 10 (3 doses a day) for people over 65 [Zito et al. 2021]. Following the medication, schedule requires "prospective memory" [Nabacino and Negretti 2020][Crystal and George Wilson 2015] which is a specifically hard task for people suffering from dementia or Alzheimer' syndrome, and in general for elder people. The introduction of caregivers to administer the medicine intake marginally solves the problem, being reliable to human error and resulting as very time-consuming.

Our objective consists of designing a safe, reliable, cost-effective smart solution based on previously proposed solutions, improving and resolving their main issues: "HexaDrawers"[Marco Faverzani 2021], "MeDiC"[Nabacino and Negretti 2020] and "Med-Drop"[Pike et al. 2021]. The final desired product includes a seamless pill intake procedure in which any non-fundamental action from the user is performed by the system.

Reliability and safety are the most important factors for our design, followed by cost (to enable more users) and intrinsic modularity. In the hopes of reducing pill intake errors, introducing more tranquillity for the families or caregivers, our design doses with high degrees of autonomy medication to patients who are unable to assert their pill intake schedule.

The project is highly scalable through 3D printing, with every module consisting of a pill magazine and a reliable delivery system, in order to overcome the risk of overdosage. Multiple modules can be stacked side by side, organized in a master-slave configuration with the master module connected to the internet for remote control of the delivery schedule and to communicate via notification/email with the caretaker.

The master module is tasked with notifying the caregiver about any deviation from the user schedule or from the system regular operation. Such messages include warnings when a pill is not delivered or taken properly on schedule; reminders when storage is almost running empty.

For optimal operation, the physical dimension of the pill determines the "type" of magazine needed; the pill is dispensed from the magazine through a sliding compartment and a load cell check the correct operation of the sliding mechanism; a photo-interrupter sensing system verifies and counts the number of pills dispensed for each individual module to ensure the correct operation of the pill selection system. Finally, each module emits a sound when it's ready for the user to intake and lights a green LED to signal which medicine needs to be taken.

2 RELATED WORKS

The first and still most common approach to improving medication adherence are pill organizers, simple containers divided into compartments to group different pills [Pike et al. 2021].

The most advanced of such devices can lock or unlock the various compartments on a time-based schedule set by the users [Marco Faverzani 2021], while also reminding the patient which pill has to be taken. Even if the risk of assuming wrong medicines during a day is mostly mitigated, the organizer requires frequent refilling by a caregiver or relative of the patient.

One advantage of schedule-based organizers is portability, being battery-based, making them a valid solution for users that roam often during the day [LiveFine 2019]. Our project however, focuses on people who are mainly located at home, either by ageing issues or mental or physical disabilities. Self-contained units are already present on the market [Health 2020][Philips 2004][PharmRight 2020], equipped with smart features.

The main drawback is the high cost of such units, not to mention their lack of modularity and scalability. To solve this issue, we are basing our design on different prototypes [Nabacino and Negretti 2020][Marco Faverzani 2021], all while keeping the cost as low as possible. Here's a list of some of the solutions discussed above and other similar products.

2.1 HexaDrawers[Marco Faverzani 2021]

A highly modular setup made of hexagonal drawers that communicate through a magnetic connector, using an innovative method through a Telegram bot in a master-slave configuration. In this way a single ESP32 microcontroller manages the whole system, keeping the prototype price as low as 20€. It however requires pre-sorting the pills by schedule, leaving such important tasks to the user or caregiver.

2.2 MeDiC prototype[Nabacino and Negretti 2020]

Due to the very simple mechanical design, this prototype shows very high reliability and precision, and it's open to further implementation for modularity. However, the refilling process is tedious and having a higher medicine capacity would require a very large and impractical device.

2.3 Med Drop[Pike et al. 2021]

This design was implemented to aid nurses to distribute medications in-home visits to VA (Veteran Affairs) patients; it is a fully mechanical device used as both a sorting tray and a pillbox, an attempt to solve the intrinsic problem of schedule based pill dispensers.

It is a great solution for its intended use but presents itself as a fully passive device with no smart related features. The announced cost of the prototype is 19.89$.

2.4 Phillips Medication Dispenser[Philips 2004]

The product can only be rented through a monthly subscription fee of 59.95$ with no initial cost, though it requires a phone line to issue alerts to caregivers of any important warning. It contains an internal backup battery and can take up to 40 days of 6 different medications.

2.5 LiveFine Automatic Pill Dispenser [LiveFine 2019]

It's the simplest commercial solution, consisting of 28 compartments that can be unlocked on a time-based schedule. Given its plastic construction, it's prone to breaking or unlocking if dropped or abused. It lacks all sorts of connectivity and we can consider it competitive only for its price tag of 89$.

2.6 Livi automated medication dispenser[PharmRight 2020]

The Livi Medication Dispenser offers a 90-day reservoir for 15 different pills with time-programmable reminders and alarms. Based on the medication size, the user is required to assemble the specific reservoir to ensure better functionality.

The device works with main power, backed up by a battery that guarantees 8 hours of continuous operation. It's not state of the art but still very capable, however, it's the most expensive solution, requiring a first 49$ instalment followed by a monthly fee of 99$, which amounts to 2,425$ over a 2-year span.

2.7 Hero[Health 2020]

With a 90 day reservoir of up to 10 medications and a fully functional and integrated app to control the device, the Hero pill dispenser can be considered the market reference point when designing a pill dispenser.

It combines all of the main desirable features such as schedule customization with reminders, fully automated pill sorting and delivery, notifications and warnings for caregivers, relevant data visualization in an easy-to-use package, all coupled with smart connectivity.

All its features come at a hefty price for extended use: a 99$ first instalment, followed by a 29$ monthly fee (795$ in a 2-years use interval).

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