Automated Pill Counter used to Fill Prescriptions by Pharmacists

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Neighborhood pharmacies typically count prescription medications manually using a pill tray. An automatic, sanitized, and accurate way to count prescribed medication would improve customer service and minimize cost. Currently available automated devices provide a partial solution to the overall problem. These available products have some disadvantages including the lack of speed and need for manual intervention to maintain counting accuracy. Improvements to current designs can be accomplished with advanced laser sensor technologies. With a programmable user interface, a user can request a specified number of pills to be counted and filled into a container. After the specified numbers of pills are counted the rest of the pills would drop into a different compartment to be added back into the supply container. The purpose of this project was to improve pill counting automation through speed, accuracy and cost, while maintaining sanitized conditions. The development of such a module would contribute toward enabling neighborhood pharmacies to fill prescription medications accurately, while improving customer service in a positive manner.

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Introduction

Prescription medication dispensing is a very long, and involved process. The pharmacist must complete many tasks which can take long periods of time, dependent on what type, and how many pills and medications are in the prescription. The duties of a pharmacists are not just limited to counting and distributing pills based on a prescription pad. Each pharmacist is required to verify the prescription, count, and recount, pill amounts, and convey clearly to the patient how to take the prescribed medication. The verifying process includes authenticating the prescribing doctor, and double checking, through calculations, the prescribed dosage. Then the prescription dosage needs to be checked if it is too high or low based on the patient information (i.e weight and age).1 When errors are found, the prescription is put on hold and the prescribing doctor is notified.

Even now in the 21st century, the preparation portion of the dispensing process at a neighborhood pharmacy is usually completed by hand. Using a sanitized pill tray and spatula, pharmacists must spread out pills on the tray and count in groups of five to ten aided with the spatula. [1] The spatula is used in order to prevent the pharmacist from touching the pills. While some pharmacies do use a tablet-counting device, these devices are currently only commercially available from a few manufacturers. Both these devices are expensive which limit accessibility for many smaller, neighborhood pharmacies. The major manufacturer, Kirby Lester (Lake forest, Illinois) produces two models of pill and tablet counting devices: the KL1 and the KL1 Plus. Both the KL1 and the KL1 Plus are reported to have 99.9 percent accuracy when counting pills and being 7 seconds faster than a manual 30 count of pills and 17.3 seconds faster compared to manual 90 count of pills.[4] The functionality of Kirby Lester models are restricted to pill counting. This shortcoming allows for the working pharmacists to insert more pills than needed, and be forced into removing pills from a counted batch. This limitation increases interest in alternative devices. Such a device is the RX-4 (RX Count Corporation, Sky Park Circle, CA).

The RX-4 is another pill counter on the market. It uses a rotating disc surface which leads into a patented gate flow design that aids in eliminating miscounts. The RX-4 has a user interface that the user can select how many pills are to be counted and fed into a vial. Once a desired count is achieved, the disc rotation ceases so no extra pills are added to the container. The process of stopping the count when reaching the correct amount of pills is the primary advantage of the RX-4 has over the KL1. The RX-4 boasts counting numbers of 500 aspirin size pills a minute and 350 capsule size pills a minute.[5] Although the RX-4 numbers overall are good to fill a 30 count prescription the KL1 is still faster. The goal of our design is to develop a system to have the speed of the KL1 with the ability for the machine to stop the count like the RX-4.

The purpose of this project is to develop and test the applicability of a pill counting device utilizing laser sensing technologies as the counting method.

Materials and Methods

Design of Prototype

The proposed design is to have an infeed funnel system that the user pours pills into which will slide into a shoot where they will be counted before being placed into a container. When the count reaches the desired amount the rest of the pills in the funnel will be directed down a different shoot and be distributed into a tray. The extra pills in the tray can be put back into the original container or placed back into the funnel to fill another prescription of the same medication. This proposed design will be designed for speed and accuracy. The module that this project is developing is the laser array to count pills as they slide through the shoot. Several designs have been developed and tested in this project in order to assess a function for a variety of pills. Each design was analyzed to determine which worked best with specific pill variables. These variables include shape, size, and type. Testing of these designs will be useful for later design stages of which option is the most suitable for all pill types.

Prototype Structure

The funnel and shoot structure was fabricated by a Makerbot 3D print using Makerbot PLA (Makerbot Industries, New York City, New York) plastic to construct the funnel, shoots, and case that will hold the system together. The design consisted of multiple pieces that connect. The shoot was made as one piece and then connected to the funnel. A portion of the bottom section of the shoot formed a hole for a small trapdoor of printed PLA plastic which will revolve on a hinge. The housing will include a digital counting display as well as a touchpad for the pharmacist to select the number of count needed to fill the prescription. The funnel system housed a laser grid which was set up according to the results from the counting tests.

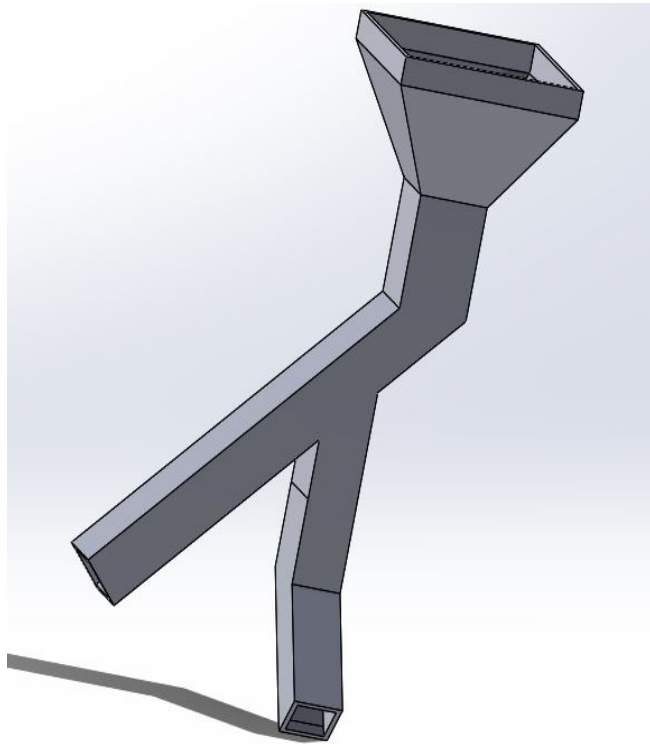

Figure 1: The above Solidworks design of the square funnel module leading into the duel shoot design

Trap Door Module

The trapdoor revolving around a hinge will be held up by a solenoid. The solenoid will retract when the count reaches the specified amount by pulling back and letting the door swing down, resulting in a hole in the main shoot for the excess pills to then fall into the separate shoot that leads to a tray. After the run is over, the solenoid expands to push the trapdoor back into place so that the main shoot is complete and ready for another run.

Counting System

The prototype of the module was constructed out of lasers with corresponding photo resistors. A 650 nm laser module was tested by sliding pills down the shoot through different laser arrays to see which arrangement counts most accurately and efficiently. The laser was flush with the inside of the shoot with the photo resistor flush against the direct opposite side of the shoot. The laser and photo resistor arrangement was tested to find the threshold for which a pill would break the laser beam to signify a count should be incremented.

Testing Methods and Results

The module of a counting prototype using laser sensing technology was developed and tested. The circuit seen in Figure 2 was used to provide experimental data using two different types of photo resistors. These photo resistors, congruently used with LED lasers, have the function of a trip wire system. A trip wire system has applications in early warning security systems, as they can detect approaching objects. A moving object which passes through such a tripwire causes a blockage in the LED laser output. The laser output is targeted at a photo resistor. Photo resistors have properties where their resistance changes based upon the amount of light exposure they receive. When a moving object blocks the emission of light from a targeted source, the resistance of the targeted resistor changes. Using this measurable change, it is possible to program a microcontroller to determine that the tripwire has been "tripped". This basic application of laser sensing technology was tested in order to show its suitability as a type of pill counting technology. Several scenarios were identified in order to fundamentally show the functionality of this technology.

Each proposed scenario had similar working conditions. The same circuit was used for all scenarios; where the two photo resistors tested were set up in series with a 1 volt DC voltage source. The lasers were operated manually at a distance of 7 inches. The lasers were directed at their respective photo resistor being tested, at an angle. Each scenario involved changing the operating voltage of a single laser which had its own independent voltage source. The LED lasers had operating voltages ranging between 2.6 and 5V. A level of 5V was considered unnecessary as the intensity of the laser beam saturated at an intensity of 3.3 Volts. Each scenario involved changing the operating voltage of the lasers between 2.6 and 3.3V. In order to achieve a variety of test results, tests were run under two separate conditions. The first condition was defined by having the circuit illuminated by ambient light from the room's ceiling light fixtures. The second condition tested the circuit while it was enclosed by a makeshift darkroom set-up. This set-up consisted of a black, non-transparent fabric which was used to completely enclose the circuit so that ambient light was not exposed to the photo resistors. Three separate laser voltages were tested: 2.6, 3, and 3.3V. The results for each test voltage are tabulated in Table 1, Table 2, and Table 3.

Figure 2. The diagram of the photo resister schematic was drawn using Pspice Design Manager. Resistor R1 represents the 10mm diameter photo resistor, while R2 represents the 7mm diameter photo resistor.

Laser contact with the photo resistors was split into three separate classifications. These classifications were: "No contact", "Contact", and "Partial contact". The "No contact" classification is described as there being no obstacle between the photo resistor and LED laser. Under darkroom conditions, the laser was left on and pointing away from the resistors. The reason for this specific setup was to ensure that excess illumination from the laser would be taken into account with the results of the experiment. Due to the functionality of the photo resistors, when no light was present, the resistance increased over the course of 10 seconds before it reaches its theoretical maximum. Thus when the "No contact" condition was tested, the minimum of the range was noted as soon as the laser "contact" was removed, and the maximum was noted 10 seconds after the initial reading. The "Contact" classification describes the LED laser as making exact, and complete, contact with the photo resistor face. The "Partial contact" classification is described as the LED laser being partially blocked by a non-transparent object. In the case of the experiments performed, obstacles of paper were folded until no light passed through between the laser and photo resistor. Whilst maintaining the "Contact" condition, the paper was slowly moved to create a partial blockage of the Laser's beam of light. Once this partial blockage was achieved, the position was held steady, while the data was recorded.

Table 1. Session 1 of Testing. The voltage applied to the lasers was 2.6 volts.

LED Laser Status	*Session 1: 2.6 Volts Applied to Lasers*			
	Ambient Light Scenario		**Dark Room Scenario**	
	10mm Resistor	*7mm Resistor*	*10mm Resistor*	*7mm Resistor*
No contact	646 Ω	646 Ω	4.8-6.83 MΩ	4.4-7.3 MΩ
Contact	565-570 Ω	431-450 Ω	3.2-5.5 kΩ	695-771 Ω
Partial Contact	621-635 Ω	510-562 Ω	9-13 kΩ	1242-1555 Ω

Table 2. Session 2 of testing. The voltage applied to the laser sis 3.0 volts.

LED Laser Status	*Session 2: 3.0 Volts Applied to Lasers*			
	Ambient Light		**Dark Room**	
	10mm Resistor	*7mm Resistor*	*10mm Resistor*	*7mm Resistor*
No contact	647 Ω	644 Ω	4.8-6.8 MΩ	4.8-6.3 MΩ
Contact	216-222 Ω	101-108 Ω	341-368 Ω	118-124 Ω
Partial Contact	340-390 Ω	294-460 Ω	570-881 Ω	420-619 Ω

Table 3. Session 3 of testing. The voltage applied to the lasers is 3.3 volts.

LED Laser Status	*Session 3: 3.3 Volts Applied to Lasers*			
	Ambient Light		**Dark Room**	
	10mm Resistor	*7mm Resistor*	*10mm Resistor*	*7mm Resistor*
No contact	642 Ω	650 Ω	0.6-0.9 MΩ	0.31-0.81 MΩ
Contact	178-180 Ω	84-93 Ω	222-312 Ω	84-86 Ω
Partial Contact	387-559 Ω	120-163 Ω	460-582 Ω	171-244 Ω

After completing the test for the trip wire system, a rough prototype was built in order to test the accuracy of pill counting. In order to test for counting accuracy and necessary calibration requirements, pills were inserted one at a time into the prototype. Setting the default system to achieve a count of 30, pills were inserted until the desired count was reached. This method of testing helped establish two major traits of calibration for the system. Due to the sensitivity to ambient environmental light, the developed code waits a specific period of time before setting the neutral steady state analog to digital converter reading. Once this value was set, the threshold value was set to be slightly below the steady state reading. The calibration value for the photo resistor was set to a low value. The low value made the machine overly sensitive to shadows in the ambient light passing over the apparatus. During the testing process, any trails which were noticed to be skewed due to a passing shadow were immediately removed, and the test was restarted and the machine recalibrated. The calibration of the machine included a delay response from the counting mechanism. In order to avoid double counting pills, a simple delay was used in the code to prevent tablets from being counted twice. After a tablet was counted, the microcontroller waits a few milliseconds in order to let the pill finish its pass through the machine.

The testing process involved the following steps. At the start of every test the machine was calibrated. Once calibration was complete the microcontroller sent out a ready response to alert the tester. The tester then inserted tablets into the device at the rate of roughly 1 tablet per second. Only one tablet was inserted in order to get test results for the two types of pills being tested. The microcontroller outputted every count to a console window on the tester's computer. This made it possible for the tester to see when the device over counted, and if it ever missed a count. This information was noted for every count. When the desired count of 30 was achieved, the number of pills actually inserted into the machine was noted. Additionally, the calibration number, to adjust sensitivity, and the response delay were changed between testing to find a wide range of results for each pill. Test results for the two types of pills are shown in Figures 3 and 4.

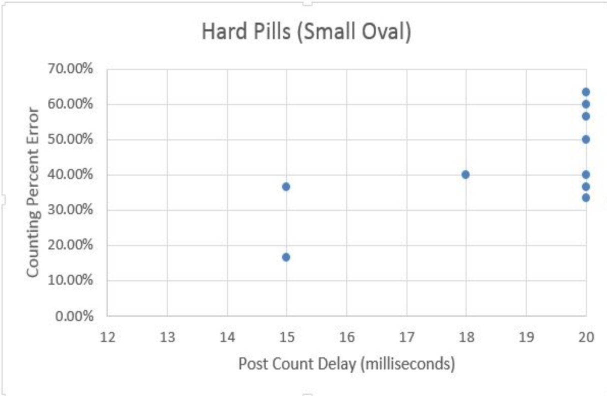

Figure 3. Scatter Plot for Large oval shaped pill test data. Shows Counting correctness in terms of error percentage.

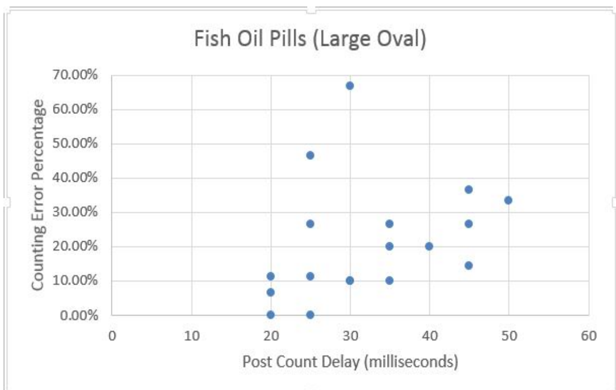

Figure 4. Scatter Plot for small Oval shaped pill test data. Due to the small size of the pills most testing was done with the same calibration rating with a 20 millisecond delay.

Conclusion and Future Directions

The results of the tests support the concept for laser technologies in pill counting devices. While the usage of a laser tripwire systems is plausible, the accuracy of the setup was limited in the prototype. Testing on the current designed prototype involved a single laser and single photo resistor. Further accuracy could be improved by implementing more lasers and resistors; however, another solution may be even better. The ambient light of the environment played a larger role in the counting sensitivity than initially considered. The overall system design could be improved by implementing a luminosity sensor rather than individual photo resistors. A luminosity sensor would have increased sensitivity while being present within an ambient light flooded room. Shadows would also have a lesser effect on the device.

Results from the testing performed could be applied to further developments in laser counting devices. While the accuracy of the designed device was lower than other products on the market, the cost is significantly cheaper. The results from this report could be used to develop new laser trip wire designs to improve accuracy while maintaining the cost effectiveness of the components used. An advanced algorithm could be written for a three dimensional tripwire array to improve accuracy. Several other redesigns could also improve accuracy. Newer more sensitive components could also increase the accuracy of the device. The tests performed in this report have shown that laser sensing technologies do have a promise for tablet/capsule counting. The future of such technologies lies in improving the accuracy and speed of these technologies. A major next step would involve performing extensive calibration tests on different shaped pills to find a list of calibration data needed for each type of pill.

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