Design of an Adaptable Sensing Platform for Metabolomic Sensing

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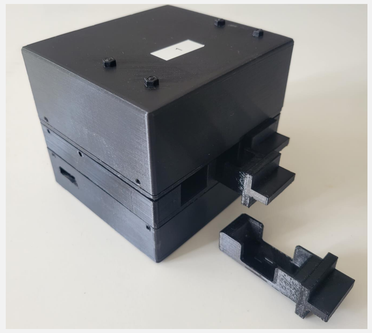
INTRODUCTION

- As of 2012, colorectal cancer (CRC) is the 2nd deadliest form of cancer for women and the 3rd deadliest for men. Screening for the disease has proven effective in reducing its mortality, so this project aims to make screening as easy and as inexpensive as possible.
- Specific concentrations of metabolites in urine have been identified as indicative of CRC. Typically, expensive laboratory Mass Spec devices are required to identify the concentrations of these metabolites and testing requires highly trained medical professionals to conduct, which makes these types of tests expensive and difficult to do.
- This project aims to bring about an inexpensive and portable sensing platform that can detect metabolite levels in urine samples through measuring low-cost quantitative color-based metabolite assays.

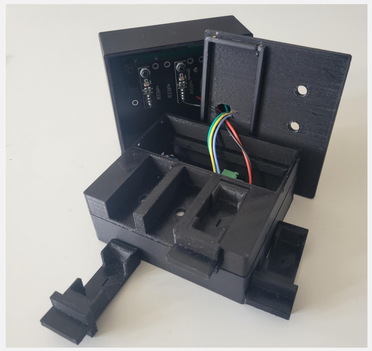
METABOLITE ASSAYS

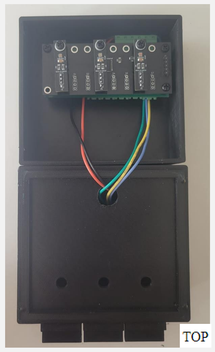
- Colorimetric reactions that will change colors quantitively according to the concentration of the metabolite within the urine samples were the key ingredient to making these assays inexpensive.
- Every metabolite will require its own colored-based assays to be developed.
- Creatinine is a metabolite of creatine, and it becomes the by-product in the process of muscle metabolism. Creatinine in urine samples can be indicative of the hydration level of the patient.
- In the case of colorectal cancer screening, creatinine is used as the normalization factor in which other metabolites can be compared across patients.

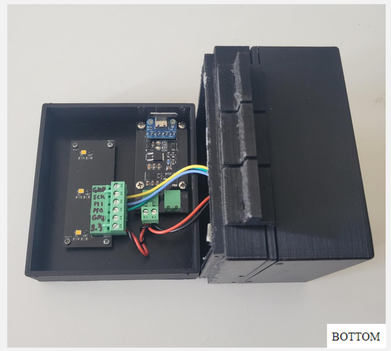
SENSOR DEVICE



- The top section of the device houses the TCS34725 color sensors and Bluetooth Low Energy module. The sensor device is fully controlled through Bluetooth using the accompanying android application.
- The middle sections of the devices have tray holders for fluidic cartridges that hold the color-based metabolic assays. Due to the nature of some specific assays, light exposure during the reaction or incubation phase can cause color developments to vary significantly, thus, a black box environment is created.
- The bottom section of the device includes the power circuit and diffused white LED light sources.







EXPERIMENTAL RESULTS

Sensor Device Results

- The result of a creatinine test is shown, three samples of 3.6mM, 10.6mM, and 21.6mM creatinine were introduced to the device.
- The Device read the samples as 2.9mM, 10.5mM, and 21.6mM respectively, achieving an accuracy of 99.8% in the mid concentrations, and 80.56 in the lower concentration.

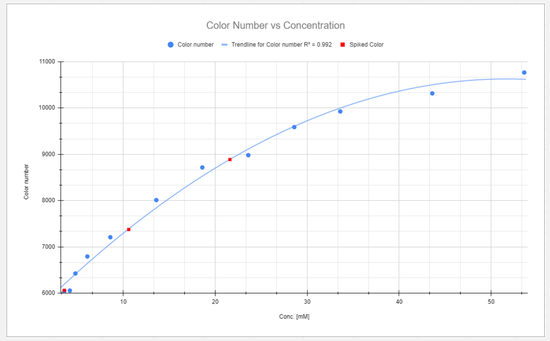
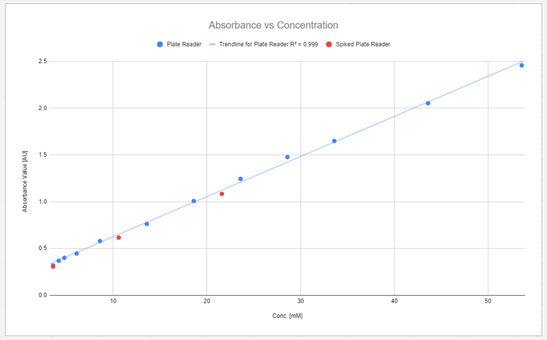


Plate Reader Results

- Same creatinine samples were put through a laboratory plate reader, values of 2.55mM, 9.8mM, and 20.7mM were obtained, respectively.
- The accuracy of the plate reader was averaged to be 94.14% for the 2 mid concentration samples, and 70.83% for the lower concentration sample, overall lower than the sensor device.



- The advantage of the plate reader is its ability to sense at high concentrations.
- The sensor device is limited to the color development of the assays, so when the reaction is reaching its peak, the color becomes more saturated and further color change will be harder to detect. Hence different calibration curves are observed.
- The sensor device showed a result of 98.96% when subjected to a test of precision

COLOR NUMBER

- The TCS34725 sensor unit uses filters and photodiodes to break down the viewed color into its alpha, red, green, and blue components. Each part of the color is recorded as a 16-bit number, which is the most common way to store color on computers.
- To simplify and better understand the results obtained from the measurement, we want to combine the alpha, red, green, and blue values into a single arbitrary constant called “color number” using the weighted sum of color percentages.
- The usage of constant a is to emphasize the importance of a large slope, a drastic change to this will likely be the dominant color of the assay. The usage of constant b is to reduce the effect of less correlating trends. The constants a and b can be any number, but a value of 1000000 or greater will be optimal for the final color number.
- Once the color number to concentration curve for the specific metabolite assay has been determined, the weighted bias “Xcolor” for each color is saved to the database, all future color numbers related to this metabolite assay will be calculated using these values.

$$\text{Red\%} = \frac{R}{R+G+B} \quad (1) \qquad \text{Green\%} = \frac{G}{R+G+B} \quad (2) \qquad \text{Blue\%} = \frac{B}{R+G+B} \quad (3)$$

$$\text{Yellow\%} = \frac{R+G}{2(R+G+B)} \quad (4) \qquad \text{Cyan\%} = \frac{G+B}{2(R+G+B)} \quad (5) \qquad \text{Magenta\%} = \frac{R+B}{2(R+G+B)} \quad (6)$$

$$\text{Color Number} = \text{Xred*Red\%} + \text{Xgreen*Green\%} + \text{Xblue*Blue\%} + \text{Xyellow*Yellow\%} + \text{Xcyan*Cyan\%} + \text{Xmagenta*Magenta\%} \quad (7)$$

$$\text{Xcolor} = (\textit{sign of the slope}) * (a^{|\textit{slope of color\% fit}|} - 1) * (b^{|R-\textit{squared of color\% fit}|}) \quad (8)$$

CONCLUSION

- Due to the lack of effective screening methods, colorectal cancer greatly contributes to cancer death.
- Quantitative color-based metabolomic reactions are an effective and inexpensive way to screen for the disease. The device designed for measuring these reactions is also inexpensive and can bring an effective screening of colorectal cancer to rural and inaccessible communities. With results of 98.96% precision and 99.8% accuracy in mid-range samples, this device has been proven capable of accurately measuring metabolites.
- This sensing device can be a platform for other metabolites as long as a quantitative color-based assay can be developed for the metabolite, the modularity is what makes this platform special, and can result in making screening for other diseases possible in the future.

ACKNOWLEDGEMENTS

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