



Exploring the Potential of an Affordable and Portable Colorimeter for Optical-Based Biological and Chemical Analyses: A User-Friendly Solution



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RESEARCH ABSTRACT

Our research focuses on addressing the critical issue of limited early disease detection, which significantly contributes to mortality in third-world countries. This problem primarily arises from the high cost of diagnostic equipment, making it difficult to procure an adequate number of these instruments. An example of a crucial yet expensive bio-diagnostic tool is the microplate reader which measures the absorbance and fluorescence of biological solutions. In this study, we specifically target the absorbance capability of the microplate reader and propose a low-cost, user-friendly colorimeter as an affordable alternative. The colorimeter effectively leverages the differences in light transmissions observed in solutions with varying colour intensities to accurately determine their concentrations. It is constructed using readily available components, such as an Arduino LED, Arduino microcontroller, TCS3200 light-to-frequency sensor, microfluidic chip, and a computer for the display interface. By developing this cost-effective colorimeter, our aim is to contribute to the improvement of disease detection and diagnosis in resource-limited settings.

RESEARCH OBJECTIVES

- Fabricate an affordable colorimetric device to measure the light absorbance of various biological solutions, enabling the determination of solution concentrations.
- Achieve comparable accuracy in absorbance experimental results to a commercial microplate reader.
- Determine micro-litre solution concentrations in microfluidic chips, encouraging the development of portable lab-on-a-chip systems for decentralised diagnostics.

DIAGRAMS

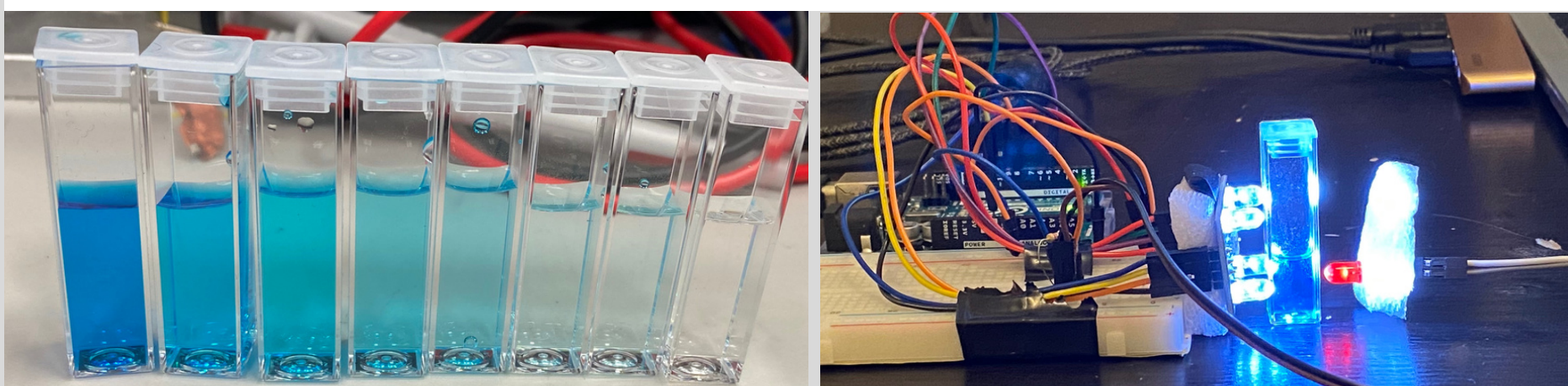


Figure 1: Solutions in Cuvettes

Figure 2: Prototypical Set Up

SYSTEM OVERVIEW: SCHEMATIC DIAGRAM

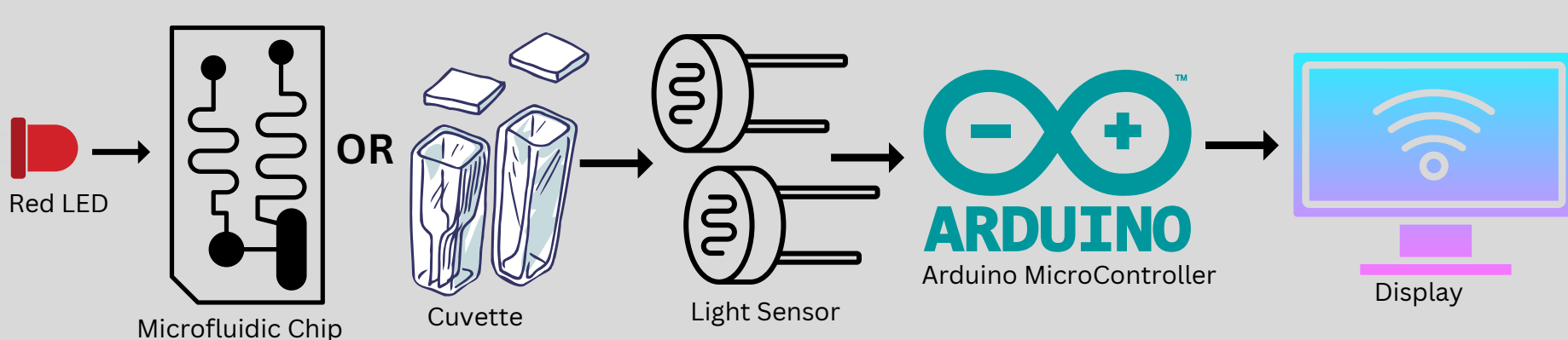


Figure 3: Solutions in Microwells

METHODOLOGY

- Both the glass cuvette and microfluidic chip setups were housed in an opaque 3D-printed casing to minimise interference from background light.
- We prepared 8 solutions of the blue dye with different concentrations.
- Abnormal protein concentrations serve as disease biomarkers | ELISA method involves protein reacting with specific substrates to form detectable coloured products.
- The blue dye was used as a surrogate to mimic the colorimetric response observed in the ELISA reaction | Successful quantification of different blue dye concentrations showcases the device's potential to detect signals produced in actual ELISA reactions.

MICROPLATE READER(CONTROL)

- Used a commercial microplate reader.
- Dispensed 10 micro-litres of each solution into separate wells.
- Measured the absorbance of the solutions at a 650nm wavelength.
- Established a baseline for absorbance readings and served as a comparison for other prototype setups.

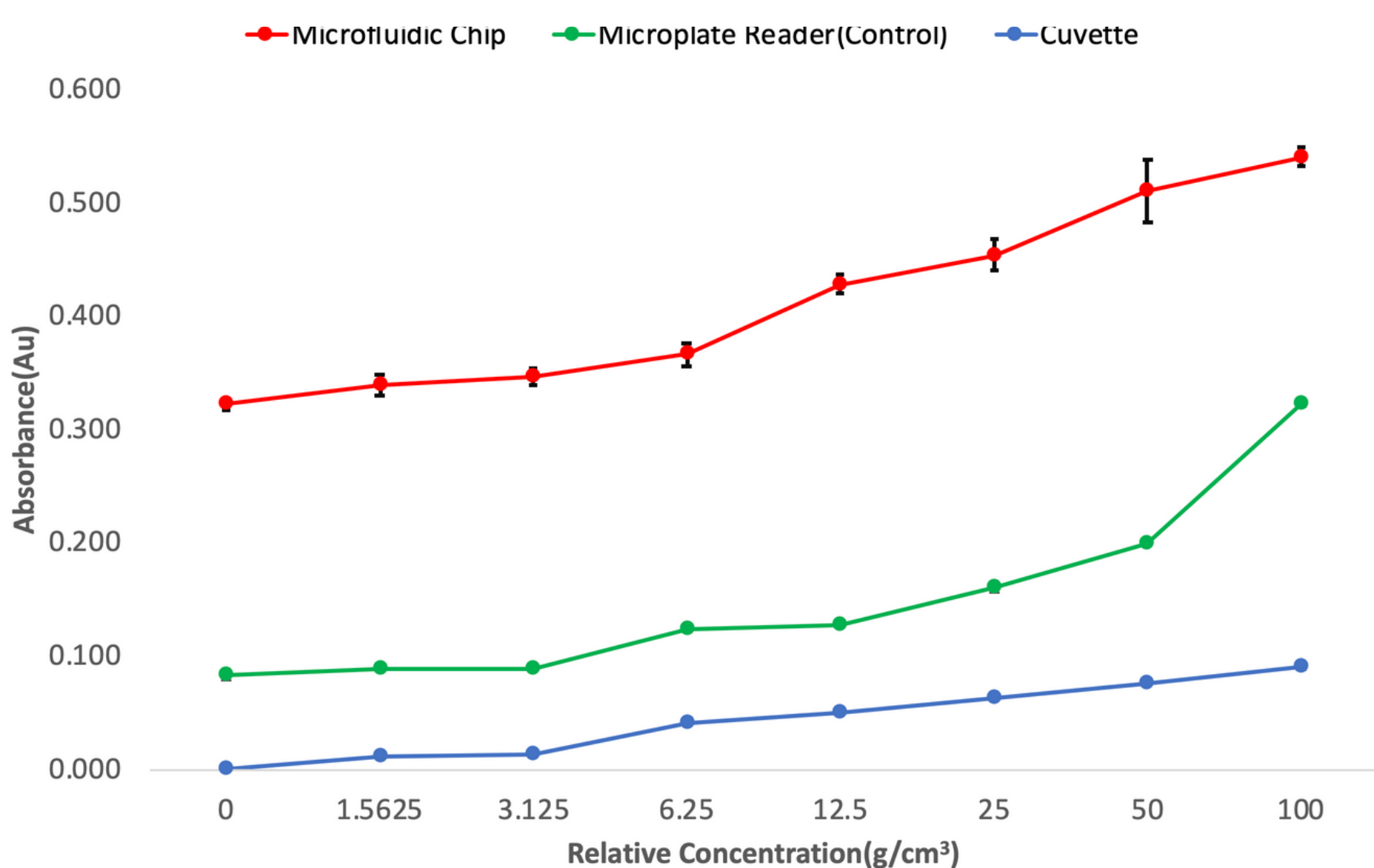
PROTOTYPE WITH CUVETTE

- Placed 2 millilitres of each solution in a transparent glass cuvette.(Figure 1)
- Programmed the Arduino microcontroller to measure light transmittance through each solution using the red LED light and a light sensor.
- Displayed frequency values representing the light intensity transmitted on the computer.

PROTOTYPE W/T MICROFLUIDIC CHIP

- Fabricated an 8-well microfluidic chip using laser printing
- 50 micro-litres in each well

RESULTS: CALIBRATION CURVE



WHY IS THIS TOPIC IMPORTANT?

- Prompts engineers to explore the path of reengineering, miniaturisation and translation of the industry lab-grade methodologies/devices into more affordable, portable and accurate versions.
- Raises awareness of the significance of early disease detection and how it could save people's lives.
- Open discussions on the potential point-of-care usage of the prototype.

WHAT IS THE FUTURE OF THIS RESEARCH?

- **Expanding to fluorescence:** Incorporate fluorescence for simultaneous detection of multiple biomarkers, surpassing the limitations of colorimetry and enabling more efficient testing with a single sample.
- **Miniaturisation and Point-of-Care Integration:** Develop a smaller, portable device for integration into point-of-care systems, enabling rapid protein concentration measurement for disease diagnosis in various healthcare settings.
- **Enhanced diagnostics and automation:** Customise the device by automating absorbance calculation, calibration curve construction, and concentration determination. Utilise AI for diagnostic outcome prediction. Design an app for displaying data and results on a phone.

CONCLUSIONS

- **Accurate Absorbance Measurement:** The colorimeter can accurately distinguish solutions of different concentrations, indicating its ability to measure absorbance values with reasonable accuracy, as indicated by the non-overlapping error bars on the calibration curve. Also demonstrates potential to be used for protein biomarker analysis.
- **Affordability and Accessibility:** The research demonstrates the feasibility of developing a portable and affordable colorimeter using low-cost hardware and open-source software.
- **Enhancing Device Design:** The device design can be enhanced by improving compactness, stability, and ease of use. Suggestions include developing a dedicated circuit board to replace the breadboard setup and incorporating a motor-driven casing for automated movement and alignment of the microfluidic chip with the optical system.

REFERENCES

- Bergua, J. F., Álvarez-Diduk, R., Idili, A., Parolo, C., Maymó, M., Hu, L., & Merkoçi, A. (2022). Low-Cost, User-Friendly, All-Integrated Smartphone-Based Microplate Reader for Optical-Based Biological and Chemical Analyses. *Analytical Chemistry*, 94(2), 1271-1285.
- Li, F., Guo, L., Li, Z., He, J., & Cui, H. (2020). Temporal-Spatial-Color Multiresolved Chemiluminescence Imaging for Multiplex Immunoassays Using a Smartphone Coupled with Microfluidic Chip. *Analytical Chemistry*, 92(10), 6827-6831. DOI: 10.1021/acs.analchem.0c01405

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