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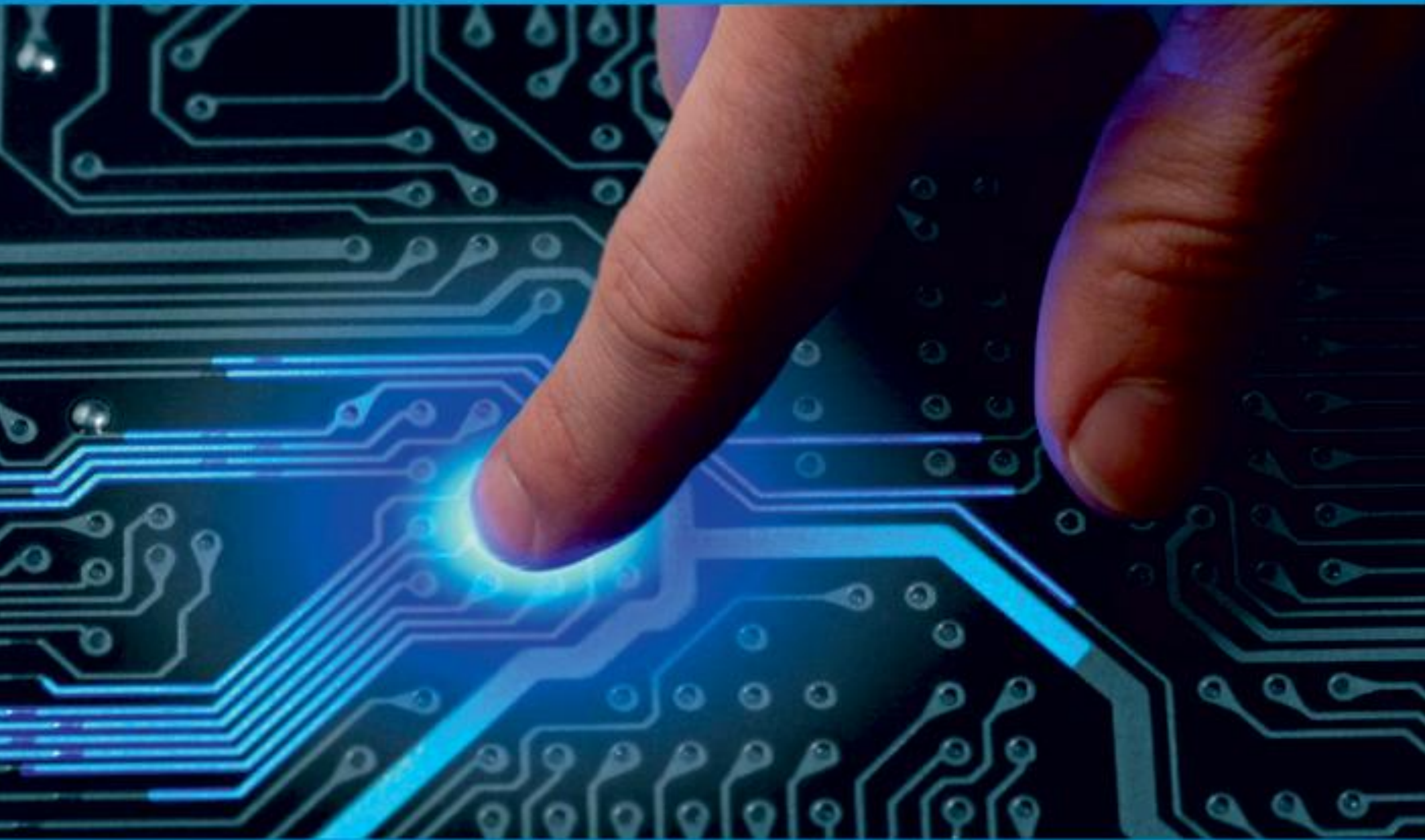

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An AI Based Design of Optical Sensor for Bacteria Detection in Water

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ABSTRACT: Our AI-based platform incorporates a user-friendly graphical interface (GUI) and utilizes an optical sensor to accurately predict and detect contamination. By analyzing the output graphs generated by the sensor, we can identify changes in drainage patterns caused by the presence of bacteria in water samples. These graphs provide valuable information for analyzing the characteristics of different samples, such as their refractive index.The accuracy, sensitivity, and specificity of the sensor have been thoroughly evaluated and compared to established reference methods. These comparisons highlight the potential of our AI-powered tool as an effective means for bacteria detection in water, with a particular emphasis on its user-friendly GUI and AI model.

KEYWORDS: GUI, AI, Sensor, Bacteria, Graph, Sensitivity, Accuracy.

I. INTRODUCTION

In developing countries, contaminated water poses significant health risks, especially for children. Photonics offers innovative measurement possibilities for detecting harmful chemicals like lead and mercury in water. A photonic crystal optical switch design based on an elliptical waveguide resonator has been developed for detecting optical wavelengths . Deep learning techniques have been utilized to efficiently detect pathogenic bacteria like Escherichia coli (E. coli) in water .To address the concern of water contamination, simple and portable methods such as paper and biosensors have been developed to detect contaminants and assess their environmental impact. Portable devices employing MTT-PMS reagents offer convenient testing for the concentration of bacteria in drinking water. Optical sensors based on one-dimensional defective binary photonic crystal structures have been employed for the detection of waterborne bacteria .To ensure water quality and prevent diseases caused by pathogens, label-free optical approaches have been employed for the detection of bacteria in food and water. Monitoring and detecting contamination in surface water are crucial global concerns. Real-time or near real-time sensors have been investigated to detect changes in water quality parameters as indicators of contamination .In summary, advanced AI models and user-friendly GUI interfaces play a vital role in the development of efficient and practical tools for water contamination detection and monitoring. These technologies have the potential to improve water quality and safeguard public health.

II. RELATED WORK

In Portable Device for Quick Detection of Viable Bacteria in Water 2022 , Access to clean water is a very important factor for human life. However, pathogenic microorganisms in drinking water often cause diseases, and convenient/inexpensive testing methods are urgently needed. (2) Methods: The reagent contains 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide(MTT) and phenazine methosulfate (PMS) and can react with succinate dehydrogenase within bacterial cell membranes to produce visible purple crystals. The colorimetric changeof the reagent after reaction can be measured by a sensor (AS7262).Compared with traditional methods, our device is simple to operate and can provide rapid (i.e., 5 min) semi-quantitative results regarding the concentration of bacteria within a test sample,

The Detection Method of Escherichia coli in Water Resources This article reviews several approaches for Escherichia coli (E. coli) bacteria detection from conventional methods, emerging method and goes to biosensor-based techniques. Detection and enumeration of E. coli bacteria usually required long duration of time in obtaining the result since laboratory-based approach is normally used in its assessment. It requires 24 hours to 72 hours after sampling to process the culturing samples before results are available. Although faster technique for detecting E. coli in water such as Polymerase Chain Reaction (PCR) and Enzyme- Linked Immunosorbent Assay (ELISA) have been developed, it still required transporting the samples from water resources to the laboratory, high-cost, complicated equipment usage,

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complex procedures, as well as the requirement of skilled specialist to cope with the complexity which limit their wide spread practice in water quality detection. Recently, development of biosensor device that is easy to perform, portable, highly sensitive and selective becomes indispensable in detecting extremely lower consolidation of pathogenic E. coli bacteria in water samples.

In Rapid, Affordable, and Point-of-Care Water Monitoring via a Micro fluidic DNA Sensor and aMobile Interface for Global Our electrochemical DNA sensor offers an attractive platform for POC diagnostics due to its compact size, portability, low cost, high sensitivity and specificity. In addition, the simple instrumentation required for electrochemical detection leads to low electrical power requirements ideal for POC use. Our electrochemical sensor implements two working electrodes, a platinum counter electrode, and a platinum reference electrode, bottom). The working electrodes contain an immobilized DNA probe in the stem-loop structure, holding methylene blue (MB) in proximity to the electrode surface, which enables efficient electron transfer with high reduction peak current , top left, and , yellow peak from green curve). When a target sequence is introduced into the chamber, it hybridizes with the immobilized probe, opening up the stem-loop structure. This specific target-binding induced conformational change generates a large decrease in the reduction peak current of MB, top right, and, cyan peak from pink curve). Once the pathogen detection is complete, a simple distilled water wash disrupts the hybridization of the target and resets the sensor for future measurements. The mobile app is the interface to the device. Its main goal is to show the end result (safe or not safe to drink) instantly to the user by automatically interpreting the results from the data obtained and making a decision based on water safety guidelines. We decided to implement the interface for an Android phone because of its recent spread through under-served communities around the world. It communicates with the device through a USB cable through which, after each experiment, the data are uploaded to the phone as a table of voltage measurements. The app processes the data and shows the result to the user immediately. The result can be presented in two formats: as a curve in a graph or as a safe/not-safe guideline . The app also keeps a log of previous results, which can be shown in a map

III.PROPOSED SYSTEM

The proposed system is a photonic-based sensor that utilizes photonic crystals for water analysis, with a focus on detecting bacterial contamination. The sensor is highly sensitive to changes in the refractive index, allowing it to differentiate between normal and contaminated water samples. By obtaining the transmission spectrum of the water, frequency shifts can be observed as the refractive index changes.

To train the system, a dataset of simulated water samples with known refractive index values corresponding to E. coli bacteria and other contaminants is created. These samples are labeled based on their refractive index values using a custom script. The photonic crystal resonator, which is at the core of the system, undergoes design and fabrication considerations to optimize cost, availability, and chip size limitations. Tools such as Rsoft CAD and Meep are used to model the photonic crystal and capture parameter changes by solving Maxwell's field equations.

The sensor captures the transmission spectrum of the water samples, and this data is processed by the artificial intelligence module. The AI algorithms have been trained on the labeled dataset to accurately identify and classify water samples based on their refractive index values. By leveraging machine learning techniques, the system can efficiently detect bacterial contamination and differentiate between normal and contaminated water.

The AI algorithms analyze the spectral data to determine the presence and type of bacterial contamination in the water sample. Additionally, the refractive index of the water sample is calculated based on the observed frequency shift in the transmission spectrum. This information provides valuable insights into the quality and safety of the water.

The performance of the proposed system is evaluated through experiments using water samples with varying contamination levels. Accuracy, sensitivity, and specificity are assessed to determine the system's effectiveness in detecting bacterial contamination. Power analysis is conducted to ensure that the sensor operates within low-energy parameters, making it suitable for portable applications.

In conclusion, the proposed photonic-based sensor system offers a fast, effective, and reliable solution for water analysis, particularly in the detection of bacterial contamination. By combining the sensitivity of photonic crystals with artificial intelligence algorithms, the system can provide accurate results and help reduce health risks associated with consuming contaminated water.

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IV. METHODOLOGY

Photonic crystal based sensor are used as diagnostic tool for analysis of water. The sensor is highly sensitive for change of refractive index. The refractive index of normal and contaminated water are different. Thus, it can differentiate normal and contaminated water. The transmission spectrum of normal and contaminated water is obtained. A shift in frequency is observed as the refractive index is changed .In this work, we have created training data by simulating the water samples with known RI of E. coli bacteria and other bacteria. Then we wrote a labeling script to label these signatures based on their RI values. Subsequently, The light propagation in photonic crystal depends on the refractive index profile. The refractive index profile of the photonic crystal resonator changes when the analyte is adsorbed on the surface. This gives rise to change in band structure of photonic crystals which will modify propagating wave properties. Rsoft CAD tool and meep is used to model photonic crystal to design and capture the parameters changes by solving Maxwell's field equation. The explanation behind the plan is to orchestrate the course of action of the issue dictated by the necessities report. This stage is the underlying stage in moving from issue to the game plan space. All things considered, start with what is obliged; diagram takes us to work towards how to satisfy those necessities. The design of the system is perhaps the most essential segment affecting the way of the item and note worthily affects the later stages, particularly testing and upkeep. System diagram delineates all the huge data structure, report game plan, yield and genuine modules in the system and their Specification is picked..

The methodology for the proposed system involves dataset preparation by loading the dataset from a CSV file, extracting relevant features and target variables, and splitting the data into training and testing subsets. Following this, two classification models, namely the Decision Tree Classifier (DT_Classifier) and Gaussian Naive Bayes Classifier (NB_Classifier), are initialized and trained using the training data to learn patterns and relationships. The trained models are then serialized and saved to disk using the joblib library, allowing for future predictions without retraining. Data visualization is performed by plotting the relationship between wavelength and the amplitude of water and E. coli contamination, generating separate graphs for combined amplitudes, water amplitudes only, and E. coli amplitudes only. These graphs are saved as image files. The overall methodology encompasses data preparation, model training, serialization, and visualization, with each step contributing to the goals of detecting bacterial contamination and analyzing water quality effectively.Additionally, the dataset is loaded using the pandas library, and the necessary features and target variables are extracted for further analysis. The dataset is divided into training and testing subsets to evaluate the performance of the trained models accurately.

For model training, the Decision Tree Classifier (DT_Classifier) and Gaussian Naive Bayes Classifier (NB_Classifier) are selected as suitable algorithms. The models are trained using the training data, which allows them to learn from the patterns and relationships present in the dataset.

To ensure future usability and convenience, the trained models are serialized and saved to disk using the joblib library. This serialization process preserves the learned parameters and structures of the models, enabling them to be easily loaded and utilized for prediction tasks without the need for retraining. Data visualization is an essential aspect of the proposed system. By plotting the relationship between wavelength and the amplitude of water and E. coli contamination, valuable insights can be gained. Separate graphs are generated to visualize the combined amplitudes, water amplitudes only, and E. coli amplitudes only. These graphs provide a visual representation of the data, facilitating a better understanding of the relationships and trends present in the dataset.Overall, the methodology encompasses dataset preparation, model training, serialization, and data visualization. It follows a systematic approach to analyze water quality, detect bacterial contamination, and provide valuable insights for effective decision-making in water analysis.

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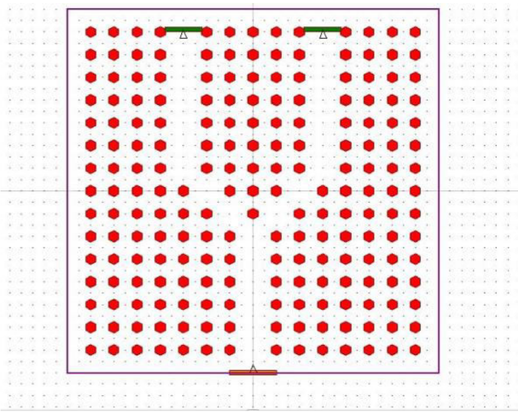
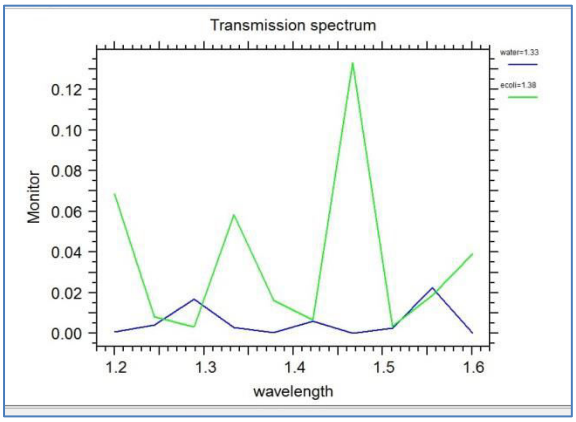
V. OUTCOMES IMAGES

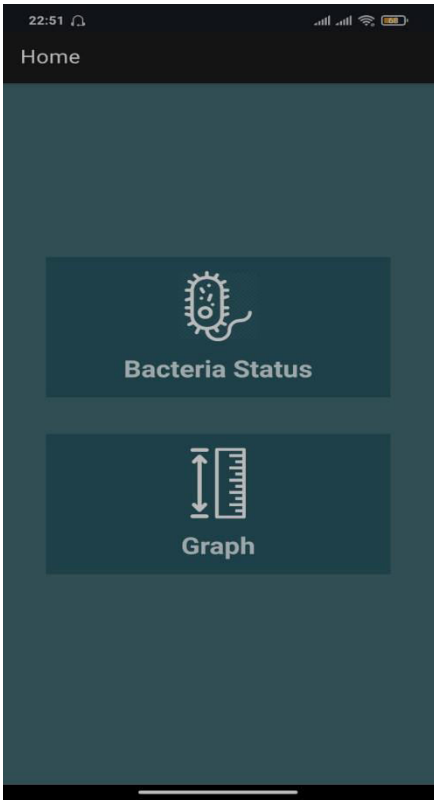
y structure of sensor

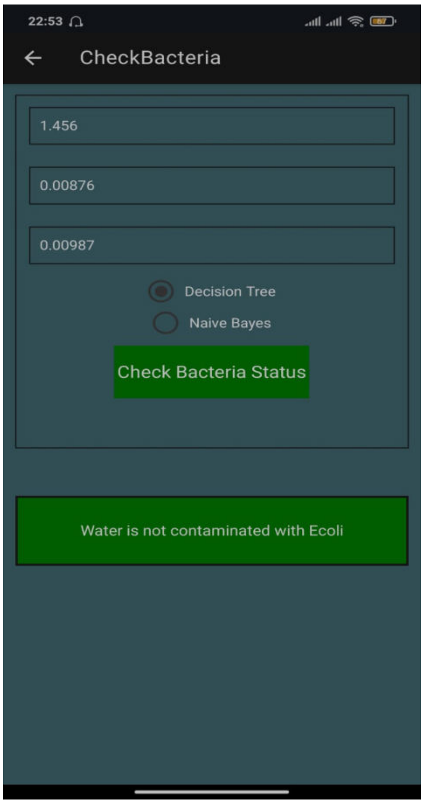


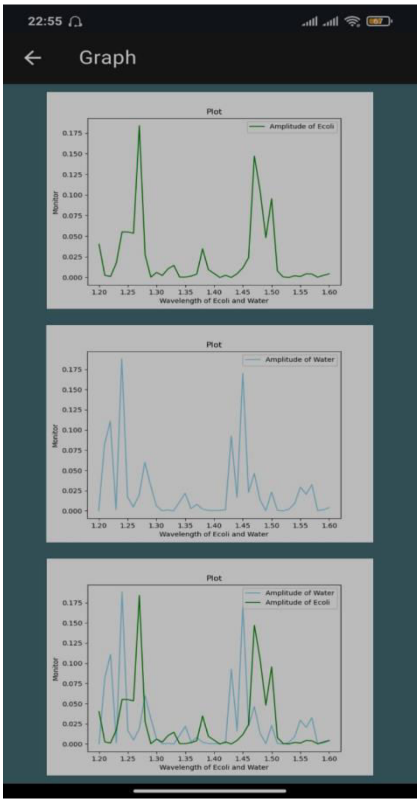
Graph of struture



Mobile Application Interfaces







VI. CONCLUSION AND FUTURE WORK

The proposed system in which the sensor structure which is made for detection of bacteria in water is stimulated. Due to variation in RI, a distinct shift in frequency is observed. The designed sensor is highly efficient as this is ableto detect a shift in the order of 1mm. Optimum input power has to be maintained for the sensor, otherwise there will be

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complete power loss at output end. The use of AI helped to segregate the patterns with accuracy of 95%.Over 2 billion people live in water-stressed countries ,which is expected to be exacerbated in someregions as result of climate change and population growth. Globally, at least 2 billion people use a drinking water source contaminated with faces. Microbial contamination of drinking-water as a result of contamination with faces poses the greatest risk to drinking-water safety. Safe and sufficient water facilitates the practice of hygiene, which is a key measure to prevent not only diarrhoeal diseases, but acute respiratory infections and numerous neglected tropical diseases. Microbiologically contaminated drinking water can transmit diseases such as diarrhoeal, cholera, dysentery, typhoid and polio and is estimated to cause 485 000 diarrhoeal deaths each year.The project aims at detecting the refractive index of pure water and contaminated water, and plots a graph showing the percentage of bacteria in water,helping people to know whether the water is pure orcontaminated before use. Thereby reducing different harmful diseases in humans.In the future, there are several potential areas for further development and expansion of the proposed system. Real-time monitoring could be implemented to enable instantaneous detection of bacterial contamination in water. Additionally, the system could be extended to analyze multiple parameters of water quality, such as pH, turbidity, and dissolved oxygen. Integration with the Internet of Things (IoT) infrastructure would allow for remote monitoring and centralized data management. The development of portable devices would facilitate water quality analysis in remote areas or field operations. AI algorithms could be enhanced to improve the accuracy and efficiency of bacterial detection and classification. Field testing and validation should be conducted to evaluate the system's performance in various real-world scenarios. Cost optimization efforts could be explored to reduce the fabrication cost of the sensor system. Finally, commercialization and large-scale deployment should be considered to make the technology accessible and affordable for widespread adoption.

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