Hand-Held Bacteria Sensor

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Abstract

A novel hand-held bacteria detector sensor has been developed utilizing Digital Inline Holographic Microscopy (DIHM). The main objective is to be able to take and process holographic images from water samples at a much faster rate than current methods; 1–4 hours to be specific. This will not only be an efficient alternative, but also a cheaper alternative to current methods. This device has been capable of detecting Escherichia coli (E.coli) concentrations from 1.2 x 10^6 CFU/mL to 1.2 x 10^8 CFU/mL. The device is capable of detecting this range of concentrations by uploading images over the internet where they are processed by means of fourier transform and other algorithms. The life and heart of the system is the Raspberry Pi 2 Model B. There is additional control circuitry that controls the pump and LED. The power consumption rate is held minimal making the case for applications at rural and underdeveloped areas stronger. An LED as the light source replaced lasers because they are cheaper and produce less noise which can have ramifications on image reconstruction. A custom designed 3D-printed coupling cap was designed to couple the LED and fiber optic cable allowing for more light to be contained and transferred. The development of this device will provide a cheap, efficient, and portable method to test for pathogens and can potentially be utilized at wastewater treatment facilities, public beaches, and medical applications, and under-developed countries.

- E. coli specifically is a Fecal Indicator Bacteria (FIB) that can indicate a possible fecal contamination in beach water, tap water, swimming pools, etc.
- According to the EPA, the current quickest detection time for E. coli is 24 hours. [1]
- A few inexpensive techniques have been developed which include a ‘hand-held fluorescence detector’ [2] The other includes a technique that uses a special chemical solution that changes the color of thecoliform E. coli in water, and uses a cellphone’s camera to record the color change. [3]

Work Plan

1. Test E. coli samples at various dilutions to properly detect the correct E. coli concentrations in CFU/mL
2. Continue collaboration with Stonehouse Water Technologies to test well water or contaminated water sources for bacteria after the samples have flown through Stonehouse’s filters.
3. Start testing urine samples provide by the Medical College of Wisconsin through a collaborative effort.
4. Design a new enclosure that is practical, ensures consistent results, and provides ease of access.

How the Device Works – Hardware & Software

Figure 1: Software Structure of Sensor

Figure 2: Schematic of DIHM Set-Up

Figure 3: Schematic of the Control Circuit

BHS Device Prototype

Figure 4: Close-up of Image Acquisition Enclosure (L), Whole System (R)

Figure 5: Custom Designed 3-D Printed LED, Fiber Optic Cable Coupling Cap

Figure 6: Environmental E. coli visualized under confocal microscope at 63X at the (a) 10^-1 and (b) 10^-3 dilutions

Results & Discussion

Figure 7: Steps of Image Acquisition & Reconstruction

ACQUISITION OF RAW IMAGE

BACKGROUND SUBTRACTION

IMAGE RECONSTRUCTION

QUANTIFICATION OF BACTERIA

Figure 8: Non-linear Relationship of E. coli Dilutions Acquired October 2015

Figure 9: Linear Relationship of E. coli Dilutions Acquired January 2017

This team was able to produce the anticipated linear relationship, Figure 9, between E. coli particle counts vs. E. coli dilution with the new enclosure depicted in Figure 4. This disproves the logarithmic relationship in Figure 8 because we ultimately concluded we were detecting clumps of E. coli in the data we acquired.

Conclusion & Future Goals

We have not produced a linear relationship for the full range of dilutions ranging from 10^-1 CFU/mL – 10^-8 CFU/mL. This is due to the complications arisen from the relatively small size of E.coli cells. Complications arise from determining what is an E.coli particle and what is not. This can be accomplished by setting a threshold for pixel size of particles. There are future hopes of implementing software that tracks the 3D motion of particles to determine whether or not the particle is real.

Applications of the New Technology

- Public beaches/parks
- Medical applications
- Water utility and waste water treatment facilities
- Developing countries worldwide

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References