A Portable Platform Enables On-Site Rapid and Sensitive Detection of Airborne Bacteria

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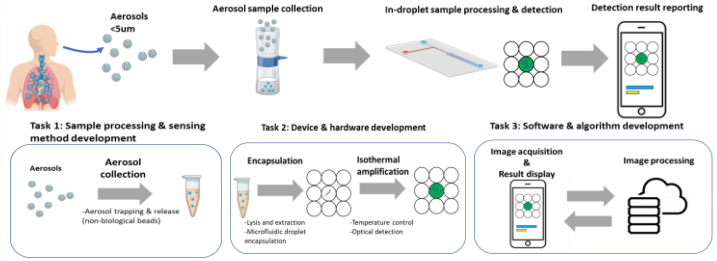
Background & motivation

Airborne pathogen transmission has caused the outbreak of COVID-19 which shows the high risk emerging pathogens pose on public health and economic loss. So, there is a need for sensitive airborne pathogen detection technologies that can be deployed for on-site monitoring.

This project aims to develop a sensitive portable detection platform to detect pathogens using microfluidic droplet-based loop-mediated isothermal amplification detection.

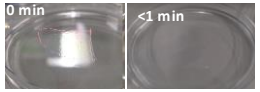
Project workflow



Task 1. Sample collection & Isothermal amplification-based detection

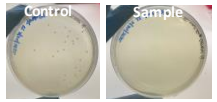
Aerosol collection → Cell lysis → LAMP based detection

Test gelatin filter for trapping aerosol sample



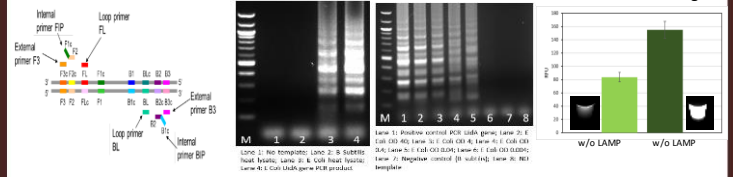
- Gelatin filter was used to trap bacteria in aerosol sample. Filter dissolved in PBS at 37 °C for < 1min.

Test lysis buffer for bacteria lysis



- Protease K was used to lyse the *E.coli* cell with 100% lysis efficiency at 50 °C for 30 mins

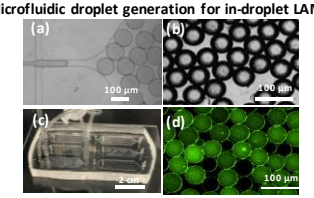
Detection of E. coil Loop-mediated isothermal amplification (LAMP)



- UidA gene from E.coli was selected for LAMP amplification with 4 x 10^3 CFU/ml (LOD)
- LAMP product was stained by calcein to generate fluorescence signal for in-droplet detection in Task 2

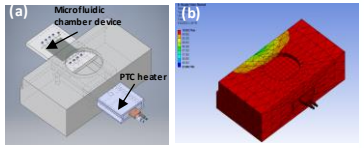
Task 2. Microfluidic device & heating module & optical detection module

Microfluidic droplet generation for in-droplet LAMP



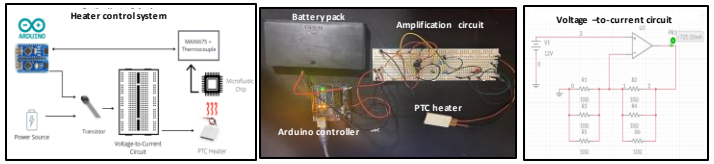
A droplet generator device (a) was used to generate monodispersed microfluidic droplets (b). Droplets containing LAMP and DNA target were collected inside a microfluidic chamber device to perform in-droplet LAMP at 65 °C incubation (c). Green fluorescence signal was produced as a result of LAMP reaction in droplets (d).

Heater housing design and simulation

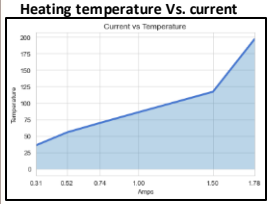


A heater housing (a) configuration was designed to incorporate both the PTC heater and the microfluidic chamber. The temperature distribution was simulated by ANSYS Workbench (b), the simulation result shows that temperature are uniform in the center region of heater.

Heating module



Heating temperature Vs. current



The heater control system includes: PTC heater, battery pack, Arduino controller, voltage-to-current circuit, and temperature measuring sensor.

PTC heater is powered by a battery pack and controlled by a custom code embedded in Arduino controller. The heater surface temperature is monitored by an IR camera to provide the feedback signal to Arduino to trigger on/off heater to maintain constant temperature.

PTC heater reaches the output temperature of 65° C at 3V or 1 A

Optical detection module

Distance between SU PVC and Optical Housing	Power in mW
0 cm	>=270
1 cm	175
2 cm	130
3 cm	100
4 cm	80
5 cm	65
6 cm	50
7 cm	40
8 cm	35
9 cm	30

A PCB has 10 LEDs array with excitation wavelength at 490 nm is attached onto optical detection module. The intensity at the through-hole location is >273mW which provides a sufficient intensity as a fluorescence excitation source to excite calcein stained LAMP product inside droplets.

Task 3. Signal acquisition algorithm & UI development

This task builds a mobile phone application to capture images of Task 2 result, process those images or upload images to cloud for cloud computing. An image processing algorithm is developed to analyze the droplet fluorescence signal. Analyzed data is stored in a cloud storage for users to access by a mobile phone or through a web portal.

Workflow of image acquisition, processing, and data reporting

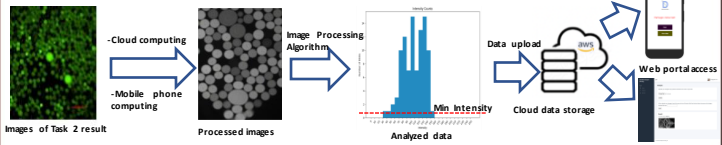


Image Processing Algorithm

Step 1: Topographic Filtering

-Detects blobs (Including touching/overlapping blobs) with different shapes

Step 2: Transformation of image into topographic map

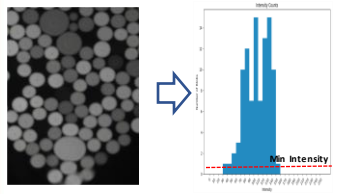
- Higher pixel intensity = Higher "elevation". Allows peaks and valleys to be defined
- Boundaries are "valleys": Valleys are determined based on pre-set parameter values

Step 3: AVG RBG intensity count of each droplet

Step 4: Determine if any droplet AVG intensity is higher than 3 times of min intensity of droplet

If Yes, report "Pathogen Detected"

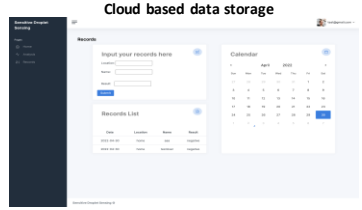
If No, report "Negative"



Front-end UI for mobile phone application

A mobile application built with the Python kivy library allows users to upload the images and get the results in a minute.

Cloud based data storage



An AWS database is built to store user accounts and data. Users access their data through a web portal or a mobile phone via authentication connected with the AWS database.

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