Determining Turbidity of Water Using Machine Learning

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Abstract - *This paper aims at generating turbidity values by analyzing samples through the camera viewpoint of one's smartphone. At present, India is water stressed and reported to have 'critical' or 'overexploited' groundwater level. The machine learning model is programmed to identify a set of weights and biases that, on average, result in low loss across all samples. In the end the app is based on this model using which users can just point their phone's camera towards the water sample and get results about the turbidity of their sample. With this system we hope to solve the problem of consumption of unsafe water to an extent.*

Key Words: **Machine learning, Turbidity, Android App, CNN (Convolutional Neural Network), TensorFlow**

1. INTRODUCTION

Access to clean drinking water is a matter of concern to this day. There have been several recorded incidents of failure in purification plants as well as accidents while supplying through pipes. Turbidity of water has a close relation to potability of water, higher turbidity levels of a given sample of water translates to poor potability and vice versa. Turbidity can be used to evaluate the look and acceptability of drinking water provided to customers, as well as the success of household water treatment and safe storage. We want to provide the consumers with an easy to-use app which lets them measure the turbidity of water at home. This project could be used by any individual who has access to a smartphone. Checking the turbidity level of water supplied to their home would be as easy as taking a picture of the water through our smartphone app. To facilitate this easy to-use application, we are using machine learning as access to turbidity sensors would neither be convenient nor cost effective for our targeted demographic.

2. LITERATURE REVIEW

Table -1: Reviewing turbidity targets (Source: WHO)

Summary of Turbidity targets (Source: WHO)		
Location	Turbidity targets	Notes
Household water treatment and storage	Needs to be < 5	For turbidities >1 NTU, it takes better purification to make it potable.
Aesthetic aspects	Needs to be < 1 NTU	"Crystal-clear" water has a turbidity of <1 NTU; at 4 NTU and above, water becomes visibly cloudy.

To understand the relation between turbidity and potability of water, WHO guidelines for purifying plants were used to set goals for this project. Targeting low turbidity levels often translates to safe drinking water and removal of pathogens. Several incidents of increased turbidity have been correlated to the spread of diseases. In a few studies reports of the relationship between turbidity and diseases have surfaced while some studies deny the correlation. Thus, although correlations may exist in individual drinking-water supplies, a uniform relationship has not been set up. Hence, turbidity should not be the only parameter the water should be judged in, it instead should be used as an easy sign to detect problems in water purification, storage, or supply. Turbidity sensors based on ISO-7027 standards are readily available which are quite accurate and accessible for us to create datasets using it. The technique used to figure out turbidity involves measurement of incident light scattered at right angles from the sample. The LDR (photodiode) generates an electronic signal based on the amount of scattering light goes through, the signal is then mapped to corresponding turbidity value.

2. METHODOLOGY

2.1 METHODOLOGY FOR TRAINING MODEL

Collect water samples (pictures) and label them using the value (in NTU) given out by the turbidity sensor. Create a dataset using the pictures and labels. Split the dataset into train and test sets. Use the train dataset to train a model using a supervised learning algorithm. Use the test dataset to determine the accuracy of the model. Deploy the model (. tflite file) to an Android app.

2.2 Methodology for Determining NTU using App.

The following methodology describes how to get camera output, this mobile application gets the camera input using the functions defined in the file CameraActivity.java. This file depends on AndroidManifest.xml to line the camera orientation. 'CameraActivity' also contains code to capture user preferences from the UI and make them available to other classes via convenience methods.

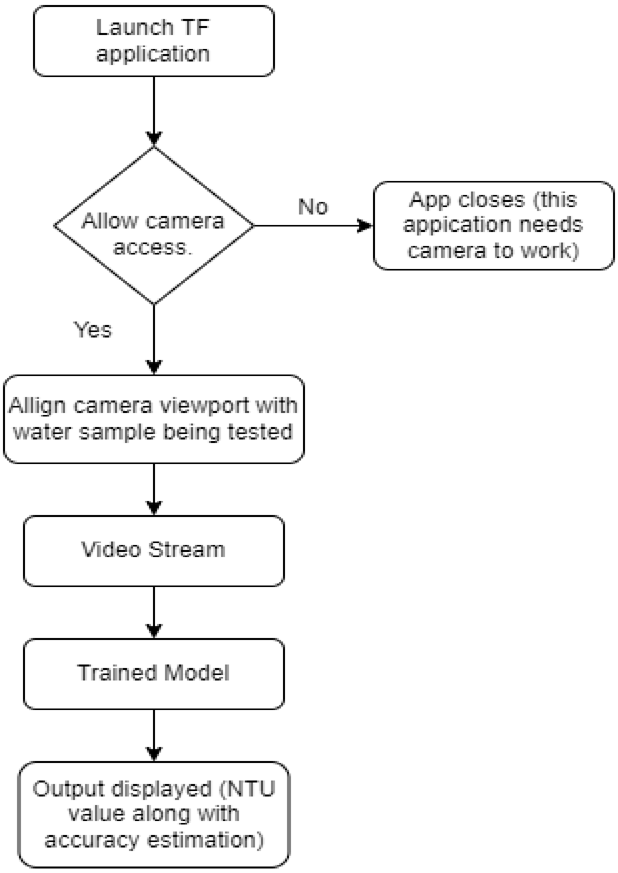

Chart -1: Flowchart for testing water sample

3. SPECIFICATIONS

3.1 HARDWARE

The project has 3 main hardware components viz: Arduino Uno, Turbidity sensor & an OLED screen.

Arduino Uno: The Arduino Uno may be a microcontroller board supporting the ATmega328 microcontroller. It has a 16 MHz resonator, a USB connection, an influence jack, an in-circuit system programming (ICSP) header, and a push button. It has 20 digital input/output pins, a reset button and many more. It comes with everything we want out of a microcontroller; it is as simple as plugging it into a computer with a USB cable, it can also be powered using an AC-to-DC adapter/battery. But it has an ATmega16U2 programmed as a USB-to serial converter.

Turbidity Sensor: This is a Turbidity Sensor with Module, this module electronically monitors and is designed to work with the Arduino, Raspberry Pi, PIC, ARM, and AVR microcontroller platforms. The Arduino Turbidity Sensor is highly efficient; it can detect and verify the quality of water by taking turbidity measurements and comparing the findings to digital or analogue signals connected to the respective pins in the accompanying electrical module. The Turbidity Sensor shines an infrared light that is not visible to human vision and capable of detecting particles which are suspended in water, measuring the light transmittance and dispersion rate using an LDR, this changes in response to the amount of TSS (Total Suspended Solids), increasing the turbidity of the liquid as turbidity levels rise. In general, this turbidity Sensor is used in projects that monitor water turbidity in rivers, streams, lakes, and many other bodies of water, as well as research sites, laboratories, and water storage tanks. It has an end that is carefully designed for direct touch, as well as an electronic module that amplifies and sends the data received to the microcontroller. Its working premise is based on the idea that when light passes through a sample of water, the amount of light transmitted through the sample is proportional to the amount of soil in the water. The intensity of infrared light diminishes as the amount of suspended soil particles in the sample increases.

OLED screen: At the heart of this module is a powerful single-chip CMOS OLED driver controller – SSD1306. It can communicate with the microcontroller in multiple ways including I2C and SPI (Serial Peripheral Interface). Thanks to the SSD1306 controller's versatility, the module comes in varied sizes and colors: for example, 128x64, 128×32, with white OLEDs, Blue OLEDs, and Dual Color OLEDs. OLED displays use organic particles which emit light on passing current through them and therefore do not require a backlight for their operation. Therefore, the display has such sharp contrast, extremely wide viewing angle and can display deep black levels. Absence of backlight significantly reduces the power needed to run the OLED. This OLED module consumes 20mA current (varies depending on the area of display being lit and the color that is being displayed). SSD1306 works in the voltage range of 1.65V and 3.3V, though the panel itself requires a supply voltage of 7V to 15V. All these different power requirements are sufficed using internal charge pump circuits. This allows it to be simply connected to an Arduino or any other 5V logic microcontroller without the need for a logic level converter.

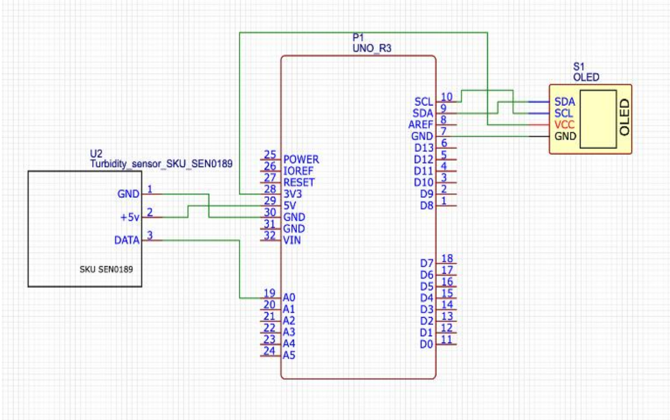

Fig -1: Circuit Diagram

3.2 SOFTWARE

This project has three main software components viz: TensorFlow, Android Studio & Arduino IDE.

TensorFlow is an open-source end to end platform that is made and maintained by Google for machine learning, the reason we chose it is because it has a lot of tools, libraries, and community resources as well that makes it easy to build and deploy machine learning power applications. We need to convert the model to a tflite file, and we use the inbuilt converter in TensorFlow to do that. Then we can deploy the model to a cloud-based service. TensorFlow enables distributed strategy which allows us to run the model over multiple GPUs, this can drastically increase computational efficiency but is not a mandatory requirement.

Libraries used:

NumPy has been used to save images as a NumPy array. OpenCV has been used to read, resize images. TensorFlow is being used to create and train the model, as well as run predictions on it. Sklearn and matplotlib help in plotting the confusion matrix once predictions have been made.

ML (Machine Learning) Model:

It takes 100x100 images as input.

It has 2 layers each having 128 neurons.

Output can be between 0 and 1000 (NTU).

Rectified Linear Unit is used as Activation Function (ReLU).

Model is fitted over 50 epochs with batch size of 16 and learning rate of 0.001

4. CALCULATIONS

Analog to Voltage conversion:

In Arduino we have one analog pin which has 10-bit resolution. analogRead() is an inbuilt function provided by Arduino IDE. Max voltage output provided by Arduino is 5V.

ADC resolution = 10 bits

= 210

= 1024

analogRead() Range = 0 to 1023

Max voltage = 5V

Analog Read to Volts = (analogRead*5)/1023

='x'V

NTU to Voltage relation:

Turbidity Range = 0 to 1000 NTU

At 0V turbidity = 0 NTU

At 5V turbidity = 1000 NTU

When the sensor is completely blocked, we receive 0V which is 1000 NTU.

5. RESULTS

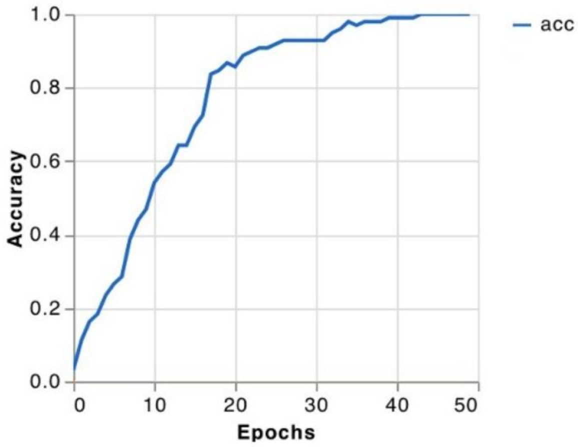

Fig 1: Accuracy per Epoch

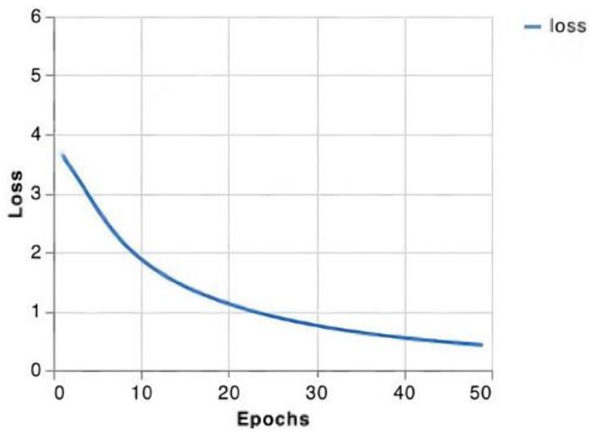

Fig 2: Loss per Epoch

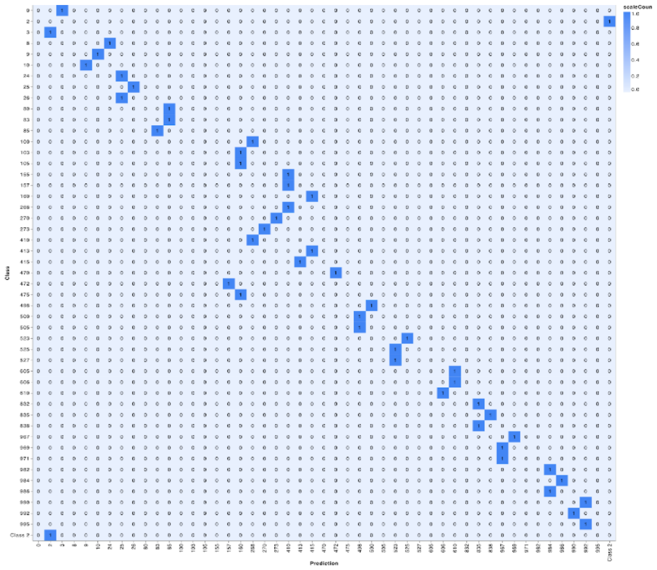

Fig 3: Confusion Matrix

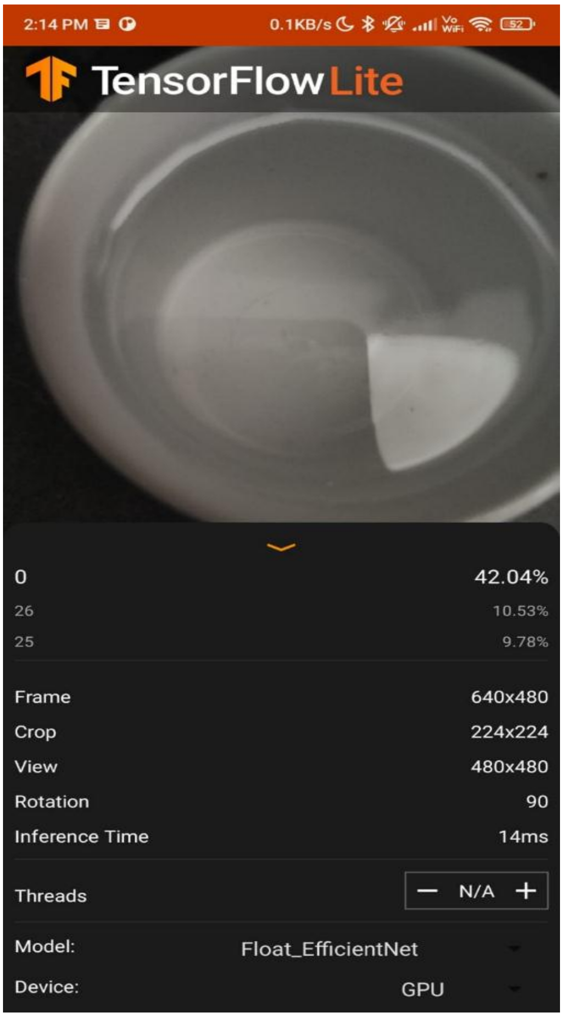

Fig 4: App calculating turbidity of water sample being tested in camera viewport

6. CONCLUSION AND FUTURE WORK

This project is a working prototype of turbidity detection using an android app. This application will help people find turbidity of their water samples in white/porcelain containers. Most of the goals set at the beginning have been met. Prospects include detecting turbidity of samples in different containers like glass, steel, etc. Also deploying the model to different platforms like iOS, iPadOS, etc. would increase the reach and accessibility of our app. Future revisions could also incorporate an online database to save the turbidity of water measured in geolocations.

This would help users as well as us to compare the data they have collected to the data in their locality. This would help keep the accuracy of the model in check. A threshold could be set for the turbidity and once it crosses a dangerous threshold for 'n' number of users, the local authorities could be alerted accordingly.

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