AquaScope- Evaluating the Effectiveness of Multimodal AI in Diagnosing Water Quality Based on Environmental Context, Sensor Data and Visual Assessment

Introduction

- Efficiently assessing water quality is required step towards aiding aquatic environments that support our communities.
  - **Today, there is no efficient way to access water quality data in the way we receive air quality or weather predictions online. This is due to how cost, and time intensive nature of water quality analysis.**
- Recently, the introduction of multimodal AI models (such as Google's Gemini and OpenAI GPT-4o) has opened new doors for how much more informative AI can be in analysis. Multimodal AI models use video, images, text, and audio as inputs unlike ChatGPT, that only uses text
- **It is crucial to scientifically evaluate both the advantages and limitations of employing AI in water quality assessment.**
  - My study evaluates multiple AI models for their accuracy in classifying water health at 12 sites across Benton County (Washington, USA), and their ability to identify meaningful features as evidence.

Hypothesis and Research Questions

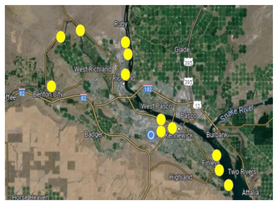
Hypothesis: A multimodal approach that combines environmental context information such as location, time of year etc. with numeric sensor data (such as pH, total dissolved solids etc.) and imagery of water and surrounding environment will increase the accuracy of diagnosing aquatic problems as opposed to only using sensor measurements.

1.Scientific utility: Is it possible to gain a detailed insight on water quality without making contact with any water? What kind of inputs (images, sensor data, site location) impact accuracy and performance of automated diagnosis the most?

2.Quantitative Validation of Hypothesis: How does the output from AquaScope agree with real-life observations in nature?

Data collection and Experiment Design

Data Collection



I used information provided by my local Benton County Conservation District to identify **12** unique sites with various aquatic diagnoses.

Not Healthy

- Debris on water surface
- Dried shrubs in distance
- Bridge in distance

Mixed

- Concrete structure
- Large Rocks

Healthy

- Unclouded water
- Present organisms

Question: Can AI models observe these characteristics and translate into meaningful conclusions?

Creating Five AI Models

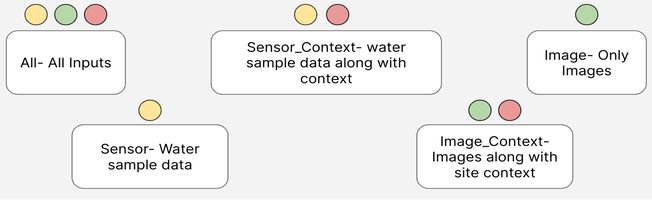
Inputs:

Water Sample Data: Nitrates, Chlorine, Hardness, Alkalinity, pH

Images - 4 different camera orientation: facing forward, left, right, facing water surface

Context: Time (Month, hour), Location, situation

AI Models:

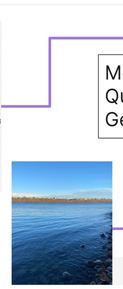


Method: AquaScope Diagnosis Generation

1.Load an excel sheet with sensor data collected at a given site. All data are stored in cloud.

2. Run AquaScope Code on Google cloud which loads data into a prompt into Google Gemini model.

	Leslie Groves
Nitrate	25
Nitrite	0
Chlorine	0
Hardness GH m	150
Alkalinity	45
pH (general)	7.6
location	Leslie Groves Pa
img left	IMG_2828.jpeg
img right	IMG_2829.jpeg
img center	IMG_2828.jpeg
img water	IMG_2827.jpeg
time	PM February 29



Model Question Generation

Gemini

Based on the data collected and the image provided, the aquatic health of the Leslie Groves Park in Richland, WA is good. The water quality is within the acceptable limits for all of the parameters tested…

```
def prompt_all(context, measurements, image):
    combined_input = [
        str(context) + " " + str(measurements)+ "
        image
    ]
return combined_input

def prompt_image(image):
    combined_input = [
        " Use the image provided to indentify if
        image,
    ]
return combined_input

def prompt_image_context(context, image):
    combined_input = [
        str(context) + " Use the information abou
        image,
    ]
return combined_input

def prompt_sensor_context(context, measurements):
    combined_input = [
        str(context) + " " + str(measurements)+
```

3.Output from prompt is saved into a Google Drive.

4. Processing 60 set of measurements takes about 8 minutes.

Data Statistics

	Leslie Groves 1	Leslie Groves 2	Blue Bridge	Howard Amon	Horn Rapids County Park 1	Horn Rapids County Park 2	River State Park	Columbia Park Pond 1	Columbia Park Pond 2	Two Rivers Park 1	Two Rivers Park 2	Two Rivers Park 3
Source	Columbia	Columbia	Columbia	Columbia	Yakima	Yakima	Yakima	Pond	Pond	Columbia-Snake	Columbia-Snake	Columbia-Snake
Nitrate	25	5	0	0	2	10	15	25	35	20	10	20
Chlorine	0	0	0	0	0	0	0	0	0.5	0	0	0
Hardness GH mg	150	300	75	150	300	150	175	175	250	300	150	150
Alkalinity	45	120	40	40	40	120	40	120	120	90	20	40
pH (general)	7.6	7.4	7.2	6.4	8	8	7.2	8.4	8.4	7.6	7.4	7.2
pH (mean)	7.15				7.733333333			8.4		7.4		
Nitrate (mean)	7.5				13			22.5		16.66666667		

A primary objective of my site selection was to obtain a diverse coverage of the following criteria: 1) visual appearance of sites: plants, water, animals, 2) numerical range: high/low pH, nitrates, etc. 3) location: near wastewater plants, type of river, 4) water quality history: has selected area has a history of water quality issues?

Data Analysis: Evaluation Methodology

	Leslie Groves 1	Leslie Groves 2	Blue Bridge	Howard Amon	Horn Rapids County Park 1	Horn Rapids County Park 2	River State Park	Columbia Park Pond 1	Columbia Park Pond 2	Two Rivers Park 1	Two Rivers Park 2	Two Rivers Park 3	Average (Model)
Source	Columbia	Columbia	Columbia	Columbia	Yakima	Yakima	Yakima	Pond	Pond	Columbia-Snake	Columbia-Snake	Columbia-Snake	
Sensor	67	83	33	75	50	67	75	100	67	67	75	100	71.58333333
Senor_Context	75	67	67	67	67	67	60	100	100	75	50	100	74.58333333
Image	75	67	100	75	60	60	67	100	60	33	100	75	72.66666667
Image_Context	100	75	75	83	67	60	75	100	80	50	100	75	78.33333333
All	80	60	80	80	100	67	50	100	75	75	60	100	77.25
Average (site)	79.4	70.4	71	76	68.8	64.2	65.4	100	76.4	60	77	90	

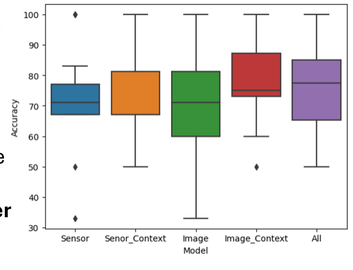
1. Given an answer produced by Gemini for a given site and a specific input combination, I read through each of the statements in the answer.
2. Labeled each statement correct or incorrect based on water quality assessments proved by local Benton County Conservation District.
3. Calculated the precision for that prediction as the number of correct statements divided by total number of statements in that answer.

Table shows precision of the AI model prediction and explanation per site. Precision is obtained from True positives (TP) and False Positives (FP)

$$Precision = \frac{TP}{TP + FP}$$

Data Analysis: Model Accuracy as a Function of Modality

- The top two highest performing models were All (**all input- images, sensors, context)** and Image_Context (**images, context)**
  - Both models had images as an input, proving them to be a useful input in aquatic analysis
  - **Essential Question: Why is That?**
- Results exhibited an **accuracy increase** of **9.4%** when images were inputted into AI models
- However, the traditional **sensor-based measurements** had a **lower variability,** making them more consistent

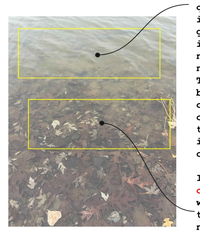


1. High throughput screening of native species for tailings eco-restoration using novel computer visualization for plant phenotyping. Science of The Total Environment, 780:146490, 2021.
2. Sustainable marine ecosystems: deep learning for water quality assessment and forecasting. IEEE access, 9:121344–121365, 2021.
3. Application of artificial intelligence (ai) techniques in water quality index prediction: a case study in tropical region, malaysia. Neural Computing and Applications, 28:893–905, 2017.
4. An interpretable hierarchical neural network insight for long-term water quality forecast: A study in marine ranches of eastern china. Ecological Indicators, 146:109771, 2023
5. A review of turbidity detection based on computer vision. IEEE access, 6: 60586–60604, 2018.
6. Pacific Northwest National Laboratory. How does a river breathe?, 2024.
7. Aquavision: Automating the detection of waste in water bodies using deep transfer learning. Case Studies in Chemical and Environmental Engineering, 2:100026, 2020
8. eplant: visualizing and exploring multiple levels of data for hypothesis generation in plant biology. The Plant Cell, 29(8):1806– 1821, 2017.
9. A deep learning interpretable model for river dissolved oxygen multi-step and interval prediction based on multisource data fusion. Journal of Hydrology, 629:130637, 2024

Qualitative Analysis: AI using Visual Features as Evidence

To explore **why** image inputs improved accuracy, I analyzed Gemini's responses. In many test cases **attributes identified in images were used as evidence for water quality.**

The presence of graffiti on the concrete structure and the lack of aquatic plants in the water may indicate that the area has been impacted by human activity. Graffiti can contain harmful chemicals that can leach into the water and harm aquatic life. The lack of aquatic plants may indicate that the water quality is not good enough to support plant growth.



However, the presence of algae in the water may indicate that the water quality is not as good as it could be. Algae can grow rapidly in water that is polluted with nutrients, such as nitrogen and phosphorus. The algae can then form blooms, which can block out sunlight and prevent oxygen from getting into the water. This can make it difficult for aquatic organisms to survive.

In addition, the presence of trash and debris in the water can also indicate that the water quality is not as good as it could be. Trash and debris can pollute the water and make it harmful to aquatic organisms.

Gemini AI Model Responses

Qualitative Analysis: Evidence-Based Explanations

The water in the lake appears to be clean and clear, and the geese in the image are a sign that the water quality is good. However, the high nitrate and hardness levels indicate that the water may be polluted. **Nitrates can come from fertilizers and sewage, and high levels of nitrates can cause algal blooms.** Hardness is a measure of the amount of dissolved minerals in the water, and high levels of hardness can make the water taste bad and can also be harmful to aquatic life.

The geese in the image are a sign that the water quality is good because they are filter feeders and they eat algae and other small organisms in the water. This helps to keep the water clean and clear. However, geese can also contribute to water pollution by defecating in the water. This can add nutrients to the water, which can lead to algal blooms.

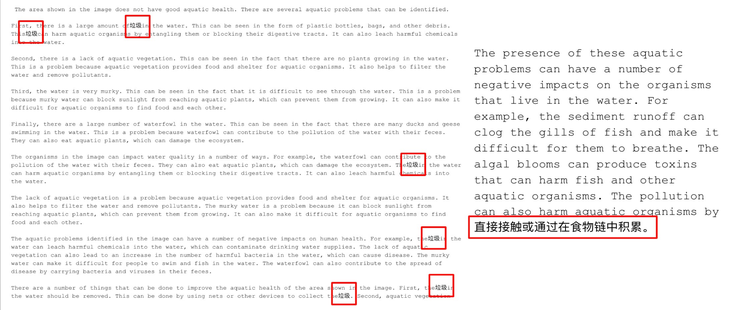
Overall, the water in the lake appears to be clean and clear, but the high nitrate and hardness levels indicate that the water may be polluted. It is important to monitor the water quality in the lake to ensure that it remains healthy for aquatic life.

AI Model Response

	Two Rivers Park 1
Nitrate	20
Nitrite	0
Chlorine	0
Hardness	300
Alkalinity	90
pH (genera	7.6

When AI Falls Short: Performance Inconsistencies of AI Models

- Consistently stated garbage and debris was an issue even when it was not present.
- **Hallucinations** - frequently observed producing parts of explanations such using Chinese script. For example, the explanation below uses Chinese script to describe the word debris/waste



The presence of these aquatic problems can have a number of negative impacts on the organisms that live in the water. For example, the sediment runoff can clog the gills of fish and make it difficult for them to breathe. The algal blooms can produce toxins that can harm fish and other aquatic organisms. The pollution can also harm aquatic organisms by 直接接触或通过在食物链中积累。

Significance and Impact

- **Image inputs increased AI model performance by 9.4%**
  - Water sample-based measurement (sensors) had lower variability
  - Images with context proved to be the most accurate model with least variability, proving that **it is possible to get a preliminary assessment of water quality without contacting water**
  - However, it is still advised to always collect data when looking to gain a detailed understanding of water quality
- These results show that the integration of multimodal AI models can greatly **increase the efficiency of water quality analysis from days to minutes.**
- **They also aid with explainability** by considering how water looks, and well as environmental phenotypes and urban features at an aquatic site
- **The success of images in site diagnosis can be a great aid in the world of citizen science by allowing many people without sensors to provide useful insight for scientists with just a click of their phone**
- However, the **hallucination of AI models remains an issue** as demonstrated by unexplainable mixed-language answers above