School of Computing
FACULTY OF ENGINEERING

UNIVERSITY OF LEEDS

Final Report

Investigation of Image Processing Techniques for Metal Detection in Water

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Submitted in accordance with the requirements for the degree of BSc Computer Science

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40 credits

The candidate confirms that the following have been submitted.

Items	Format	Recipient(s) and Date
Deliverable 1, 2, 3	Report	SSO (DD/MM/YY)
Participant consent forms	Signed forms in envelop	SSO (DD/MM/YY)
Deliverable 4	Software codes or URL	Supervisor, Assessor (DD/MM/YY)
Deliverable 5	User manuals	Client, Supervisor (DD/MM/YY)

Type of project: Exploratory Software

The candidate confirms that the work submitted is their own and the appropriate credit has been given where reference has been made to the work of others.

I understand that failure to attribute material which is obtained from another source may be considered as plagiarism.

Kang Liu

Summary

<Concise statement of the problem you intended to solve and main achievements (no more than one A4 page)>

Acknowledgements

<The page should contain any acknowledgements to those who have assisted with your work. Where you have worked as part of a team, you should, where appropriate, reference to any contribution made by other to the project.>

Note that it is not acceptable to solicit assistance on ‘proof reading’ which is defined as the “the systematic checking and identification of errors in spelling, punctuation, grammar and sentence construction, formatting and layout in the test”;
see http://www.leeds.ac.uk/gat/documents/policy/Proof-reading-policy.pdf.

Contents

Chapter 1

Introduction

1.1 Project Overview

1.2 Project Aims

This project focus on metal detection in water through image processing techniques. The main aim is to develop an image processing algorithm to achieve metal detection. This algorithm will use an image taken by the user as input, it will then analyse and extract the feature in the image to get the concentration of the metal.

Alongside the main aim of the project, the secondary aim of the project is to develop and provide a generic mobile application platform.

1.3 Objectives

1. Develop a base mobile application that allows users to upload data and get results.
2. Develop a web service that receives users' requests and sends the results back.
3. Design and evaluate image processing algorithms that detect the concentration of metals in water.
4. Reflect on limitations and possible future improvements to the mobile application, web service and image processing algorithms.

1.4 Deliverables

1. An android application developed by Android Studio.
2. A web service developed by Python Flask and deployed in Pythonanywhere.
3. Two image processing algorithms have been implemented and compared for evaluation.
4. Future improvements discussed in this report.

Chapter 2

Planning and Project Methodology

2.1 Planning

2.2 Project Methodology

2.3 Risk Mitigation

Chapter 3

Background Research

3.1 Introduction

Rapid development of industrial factories and progress in related technologies are causing increasing environmental problems [1, 3]. Most of heavy metals are non-biodegradable and can easily accumulate in ecological systems which makes them one of the most problematic pollutants. Heavy metals can also be harmful to public health. For example, cadmium (Cd) can accumulate in kidney and liver for over 10 years and affects physiological functions of a human's body eventually [4]. As a result, it has become significant to accurately detect and monitor heavy metals in the industrial processes and environment.

3.2 Current Detection Methods of Heavy Metals

Many techniques have been developed for the detection of heavy metals, including inductively coupled plasma mass spectrometry (ICP-MS), inductively coupled plasma-atomic/optical emission spectrometry (ICP-AES/OES), electrothermal atomic adsorption spectrometry (ETAAS), and so on [2]. Many of these techniques have high sensitivity, specificity and accuracy. But these methods all require complicated facilities, professionals, and complex operation. Therefore, in developing countries and regions with a lack of sufficient infrastructure, professional experts, and appropriate environmental treatment, there is a high demand for simple, efficient and portable detection methods.

Considering above concerns, paper-based analytical devices (PADs) is one of the most promising solutions, which is cheap, simple, sensitive, specific, accurate, user-friendly, and environmental-friendly [2]. Thurs, we choose to use the results of PADs in this project.

3.3 Paper-based Analytical Devices and Sample Images

There are three main steps in the metal detection through PADs. First, the water sample is dipped on filter paper. Second, a specific reagent is applied to know the existence of particular metal. Third, the application of specific reagent to water on filter paper will produce only a single color showing the existence of particular metal and its intensity. There exist special types of chromogenic chemicals known as reagents which are reactant to a particular metal. For instance for cobalt(Co) and zinc(Zn), chromogenic reagents are 4-(5-bromo-2-pyridylazo)-N,N-diethyl-3-hydroxy-aniline (5-Br-PADAP) and dithizone (H2DZ), respectively.

Due to the limitation of the experimental conditions and available data, we focus on three metals' detection: cobalt(Co), hydrargyrum(Hg), and nickel(Ni). Figure 3.1 below shows examples of three metals' detection results, ppm (parts per million) is the unit of concentration which is the mass fraction of solute per million.

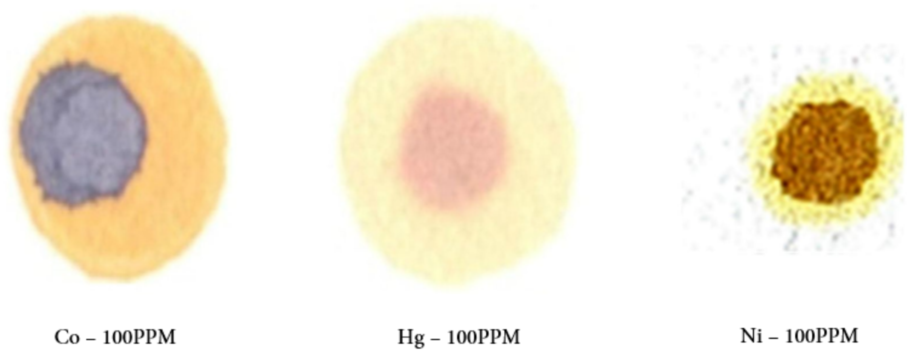

Figure 3.1: Examples of three metals' appearances on PADs with concentration 100PPM.

3.4 Color Detection

Color detection is an important step in image processing. It is to classify pixels into different color regions from a given image [6]. Specifically, the aim of color detection in this project is to find the area showing the existence of particular metal and its intensity which is also called region of interest. As the results of this project are based on chemical reaction, environmental factors can easily cause decline in image quality like background noise, motion blur, or shadowing effects. So, image pre-processing needs to be carried out to partially reduce the impact of environmental factors on the images.

3.5 Color Space

There are many kinds of color spaces (also called color models) used for image representation, each with their own strengths and weaknesses [6].

First, RGB color space is the most frequently-used color model in computer storage. It has three color channel red, green and blue corresponding to the intensity of each primary color. The value of each color channel usually ranges from 0 to 255 in computer. The main advantage to use RGB color space is its simplicity which is easy to store, configure and display the image in all kinds of devices. However, some important color properties, such as brightness and purity, are embedded within the RGB color channels. So, it can be difficult to determine the specific colors and their reliable working ranges [6].

The other commonly used color spaces for image processing are the hue-based color models.

They usually include: Hue-Chroma-Value (HCV), Hue-Chroma-Lightness (HCL), Hue-Saturation-Value (HSV) and Hue-Saturation-Lightness (HSL). In these models, hue represents the color angle, chroma or saturation represents the color purity, value or lightness represents the color brightness. Hue-based color models tend to be a favourable choice for colour detection because they separate important properties such as brightness and purity from the image. This allows better separation between different colours and thus they are the preferred colour models for various colour detection applications [5].

3.6 Color Distance in RGB Space

$$f'(x) = x^2 + xwherex = \tag{3.1}$$

3.7 K-Means Algorithm

3.8 Image Histogram Matching

3.9 Existing Applications in Past Papers

Chapter 4

Implementation

4.1 Mobile Application

4.2 Web Service

4.3 Image Processing Algorithms

4.3.1 Image Histogram Matching

$$Similarity = \cos(\theta) = \frac{A \cdot B}{\|A\| \, \|B\|} = \frac{\sum_{i=1}^{n} A_i \times B_i}{\sqrt{\sum_{i=1}^{n} A_i^2} \times \sqrt{\sum_{i=1}^{n} B_i^2}}$$

4.3.2 K-Means & Linear Regression

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Chapter 5

Software Testing and Evaluation

5.1

Chapter 6

Conclusion

6.1

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Appendices

Appendix A

External Material

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Appendix B

Other External Material

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