University of Southern Queensland

Faculty of Health, Engineering and Sciences

Air Particle Monitoring using Image Processing

A dissertation submitted by

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Abstract

Various studies indicated that inhaled microscopic air borne dust particles with diameter less than 10 micrometers (PM10) can cause significant effect on human health such as heart disease, asthma, stroke, bronchitis and other respiratory diseases. This is due to their ability to penetrate deep into the blood stream and embed themselves in the lung tissue and alveoli.

The aim of this project is to develop a portable low-cost air particle monitoring systems using image processing techniques. Research was conducted on current literatures based on image processing techniques. Existing methods of monitoring air quality of the surrounding environment has not been fully utilized with image processing techniques. The advances in technology in image processing and its mass uses means it can be afforded at low cost. This system can be commercialised and with the aid of internet protocols the data can be accessible for real-time observation.

A image processing methodology was investigated, developed and implemented. The investigation of this methodology include the investigation on moving images and processing of these images frames.

The existing literature was investigated, and image processing techniques for backscattering and reflection methods were researched. The researched investigated on frame integration and reduction of noise using normalization and averaging (Yi, Peng & Xiao 2009),(Yang, Xue & Tian 2005*a*), and conversion of video frames to picture frames. These methods were used in processing of the recorded videos.

When image processing techniques were discovered, the implementation of those techniques was a prototype to detect microscopic particle using methods based on backscattering and reflection of light. In the experiments conducted the results evaluated showed a detectable level of different amounts of dust concentration in per cubic meters. Analysis showed that image processing monitoring system designed was a viable option to available air quality monitoring systems in public areas and industries.

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Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Newman Sana

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Signature

Date

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Nomenclature

PM10: Particulate matter with diameter of 10 micrometers

PM2.5: Particulate matter with diameter of 2.5 micrometers

WHO: World Health Organization

NAAQ: National Abient Air Quality

NHMRC: National Health and Medical Research Council

TSP: Total suspended particulates

CCD: Charge-coupled device

Chapter 1

Introduction

1.1 Air Pollution Monitoring Systems

The rapid growth in population, urbanization, industrialization and motorization have become the most significant sources of increase in air pollution concentration. It has become a serious issue in most parts of the world today. This has raised the concern over monitoring of airborne microscopic dust particles for two main reasons. First, such particles cause public health problems and second, atmospheric aerosol particles, have shown to have a significant influence on atmospheric climate at a local and global scale (Wong, MatJafri, Abdullah, Lim & Low 2007*b*). The particle's mass concentration and size distributions are very important to the aerosol's impact on human health. A number of scientific studies showed that the most harmful elements in air pollution is microscopic dust with diameter less than 10 micrometers. (Saleh, Lim, MatJafri & Abdullah 2007). These dust particles penetrate deep into blood streams and embed themselves in the lung tissue. The effects of this microscopic dust has led to diseases such as lung cancer, asthma and impairment of the immune system (Guo, Pesch, Schneider & Grimm 2011).This has motivated engineers to design, develop and implement monitoring systems.

The first and earliest methods developed were application of Ringelmann number system and Bacharach system. Ringelmann method utilises the degree of greyness, where 'clear' to 'black' is graded 0 to 5. Ringelmann method expresses the plume collected in terms of Ringelmann number and compares the greyness of the plume with a standard chart known as Ringelmann chart. This method provided a standard for estimation of particulate emissions. The result is obtained by visual observation . However, it is highly subjected and liable to error -particularly due to weather and daylight conditions(Clarke 1998). With the Bacharach system volume of gas is controlled from a flue and drawn manually from a exhaust vent through a paper filter. The colour of the residue collected on the filter paper is then compared with a Bacharach scale. This system is ideal for assessing the amount of smoke produced by a combustion system (Clarke 1998).

Furthermore, additional research was carried out to improve on the previous system types, which led to a development of a system types based on optical theory. These systems utilise the principle of light absorption, light scattering and light reflection. They use stacks or ducts and a fixed light source to emit a collimated beam, the intensity of which is controlled through a feedback from a reference detector. The beam is split so that part is received by reference surface for calibration check, and part is guided to pass at a selected angle through a particulate sample. The absorbed and backscattering or reflecting optic energy from the particles in the sample is detected by sensor to provide an indication of particulate concentration.

The growing concern with the air pollution has created the need to develop advanced monitoring systems with capabilities far exceeding the performance of the methods and equipments that were used (Hariharan 2010). The major attraction was the photographic technique, the continuous and rapid evolution of digital technologies in the last 20 years has incredible improvement in the digital technology (Wong et al. 2007*b*),in information and communication technologies and personal computer technology. This technology allows to transfer data over Internet protocols which provide real time observation and image processing.

There are number of techniques which have been developed to efficiently and accurately monitor air pollution. One technique commonly used is based on image processing techniques, which include advanced land observing satellite images and surveillance cameras. Advanced land observing satellite images use a remote sensing method aided with surveillance cameras. The information of the atmospheric pollution heavily depends on the ground reflectance. Due to high cost of building monitoring stations across different regions, there are a limited number of stations in use.

1.2 Project Aim

The primary aim of this project is to design, develop and implement an air quality monitoring system based on backscattering and light reflection method which address the limitations of existing air pollution monitoring systems. The system will utilise image processing software . The software system is to record the captured images and convert the video in a way which is easily accessible to the user. In the interest of the user accessibility, the system must be fully independent in operation once it has been configured. The system must be capable of operating in any location and be able to work in real time observation.

This project aims to investigate and compare the proposed system with existing image processing techniques and algorithms designed for this application. This system will use MATLAB software to process images captured to usable data.

1.3 Project Objectives

This project was assessed and broken down into a number of deliverable outcomes for completion.

- Identification of the limitation inherent in exiting monitoring systems.
- Investigation of the image processing methods applicable to air particle monitoring systems.
- Development of a software prototype for determining dust concentration..
- Recommendation for supporting hardware and software systems.
- Analysis and evolution of the system.

1.4 Overview of the Dissertation

This dissertation is organized as follows:

Chapter 2 discusses the importance of the application and existing solutions to the problem. Investigations on existing systems is to recommend a basis to develop a new system. Image processing techniques are discussed and further implementation of new developments are determined.

Chapter 3 defines detained methodology for research, design , development and implementation of the system's hardware and software.

Chapter 4 details the design, development and implementation of the software system. This includes the development of the algorithm using MATLAB to process images.

Chapter 5 identifies the performance of the system to make recommendation on its application and analysis of experiment results.

Chapter 6 summaries the work performance and identifies the further research and development.

Chapter 2

Literature Review

2.1 Introduction

In developed countries, air pollution management is a considerable rise in public awareness and significant concern in recent years (Williams & Larson 1995) . According to (Almselati & Rahmat 2011), the problem of air pollution is the result of population growth, urbanisation, industrialization and motorization. This has led to close monitoring of excessive emission of air pollution. In the last ten years, electronic means were used for monitoring dust particles. With the continuous and rapid evolution of advanced digital research in the past years, there had been incredible improvement in digital technology, information and communication technologies and personal computer technology. This modern digital technology replaced the existing methods and provides real time observation and image processing.

The discussion in this chapter examines issue of health problems and the existing systems based on backscattering and light reflection methods for air particle monitoring and their specific applications. The operation of this systems and the task they performed were examined, and the literature discussion on specific implementation for the system types were analysed. This includes the image processing techniques application to process data to useful information.

2.2 Dust Monitoring

Why is it important to monitor air quality?

According to (Holli Riebeek 2009), poor air quality threatens the health of all living organisms from humans to plants. The air pollution monitoring systems outlined in section 1.1 provided adequate and accurate results. Due to excessive emission of pollution into the atmosphere, more research have been conducted into developing low cost and portable systems.

2.3 Health Issues

The most common effect associated with air pollution management is the impact on human health .The most evident air pollution example is the extensive build up of smog in Beijing, China that engulfed the city (Watanabe, Yamaguchi, Nakayama, Gao, Nagasawa & Ozawa 2000*a*).

Figure 2.1: Beijing, China Pollution USA TODAY (2013)

At present China is at rapid growing stage of industrialization and urbanization, large amount of air pollution is emitted into the environment by large scale industrial production (Cheng, Cao & Collier 2008*a*). According to (Cheng et al. 2008*a*),World Health Organization (WHO) estimated that there are 2.7 million deaths from air pollution every year globally. Air pollution has become a serious issue in any part of the world today. This has raised concerns over monitoring of microscopic dust particles for two main reasons. First, such particles cause public health problems and secondly, atmospheric aerosol particles shown to have significant influence on atmospheric and climate at local and global scale (Wong et al. 2007*b*). The particles mass concentration and size distributions are very important to the aerosol's impact on human health.According to (Cheng et al. 2008*a*),the most harmful elements in air pollution are the microscopic dust with diameters less than 10 micrometers (PM10). These dust particles penetrate deep into blood streams and embed themselves in the lung. The effects of these has led to diseases such as heart disease, asthma, stroke, bronchitis and other respiratory diseases (Guo et al. 2011). Also the research of America Cancer Association indicated that with the rising number of $10\mu g/m^3$ particles in the air increase the fatalness of total mortality by 4%, corpulmonale mortality by 6% and lung cancer by 8%(Cheng et al. 2008*a*).This has become the world's attention to monitor indoor and outdoor air quality (Han et al. 2010).

2.4 Emission Standards

The standard of dust emission is different for each country locally and internationally. The harmful components in the air are measured in density. According to (Watanabe, Yamaguchi, Nakayama, Gao, Nagasawa & Ozawa 2000*b*), the average standard dust concentration in a living environment ranges from $40\mu g/m^3$ to $80\mu g/m^3$. This standard again differs according to the type of pollution hazards in an area, for example in urban areas the air quality monitoring focuses on the pollution from vehicle exhaust, power stations and pollution generated from factories. In industrial sites such as mining, the monitoring systems are implemented to monitor chemicals, toxic fumes/gases and dust from manufacturing and transportation.

In the manufacturing and mining industries, dust concentration is a threat to the health and well being and safety of the workers. It is very important to measure the dust concentration precisely in real time. The dust will not only cause harm, but could also cause an explosion within certain concentration (Fengying & Hongyan 2010). Due to this harmful effect, the National Ambient Air Quality (NAAQ) in the United States of America and the Health Management Standards in Japan have set $150\mu g/m^3$ as the allowable dust concentration in working environment (Watanabe et al. 2000*b*). In Australia, emission standards are set by state governments, this is applied to the discharge of gasses emissions containing dust (Howard,B.and Cameron,I. 1998).As a absence of fixed regulatory standards relating to dust emission, it is common practice to use best environmental practices. An example is a Aluminium refinery in Western Australia utilises a 24 hour target value of 120μg/m^3 TSP (Howard,B.and Cameron,I. 1998).Recently the general guidelines regarding the maximum ambient dust concentration were endorsed by the National Health and Medical Research Council (NHMRC) and the Victorian Environmental Protection Authority for PM10 standards reflecting the importance of human health issues (Howard,B.and Cameron,I. 1998).The emission standards are listed in table 2.1.

Table 2.1: Emission Standard

Guidelines used by regulatory bodies				
PM10	PM2.5	Deposition	Average period	Source
50μg / m^3	15μg / m^3		Annual	USEPA(1999)
150μg / m^3	65μg / m^3		24hr	Victorian EPA
120μg / m^3			24hr	Victorian EPA
40μg / m^3			Annual	NSW EPA (1998)
30μg / m^3	To be developed		(Long term)l	NSW EPA (1998)
50μg / m^3	To be developed		24hr	NSW EPA
		$4g/\ m^3$ / month		

2.5 Existing Monitoring Systems

This section provides the information on typical monitoring systems, which are commercially in use in industries and public areas. The information shared here are from various resources detailing applications of optical devices, mobile sensor monitoring systems and image processing techniques.

2.5.1 Optical Devices

The first, accurate and efficient digital systems developed to monitor air pollution are known as Optical measuring devices. Such devices are known as opacity monitors, opacimeters, transmissometers and smoke density monitors. According to (Clarke 1998), these devices consist of light source mounted on one side of the duct/ chimney, and transmit visible light across the duct towards a receiver on the other side of the duct.

2.5.1.1 Opacity Monitoring System

Opacity monitoring systems are used in power plants and other applications in exhaust gases in industries, particularly to monitor fly ash of gas passing through stacks of coal -fired boilers (Thomas, R, Eluclid & L. 1983). IIt consists of a light source mounted on one side of a duct and a detector on the opposite side of the duct. The system is periodically calibrated to determine a true zero reading and an accurate upscale range for an opacity reference (Thomas et al. 1983). It measures how much light is blocked by the gas particulates flowing through a conduit or a stack (Michigan.gov n.d.). This measurement of the opacity for the gases is a measurement of the amount of particles or smoke in the gas. The accuracy of the system is maintained by keeping the optical window clean. However, contamination to the optical windows would produced false opacity reading.

2.5.1.2 Opacimeter

Opacimeter is an instrument for continuous measurement of exhaust gas opacity. It is classified into two types, a light reflecting type that measures smoke concentration based on the changes on the reflectivity when light is shown on the PM10 collected on a filter, and the light transmitting type that measures smoke concentration based on the strength of the absorbed and scattered light when light is shown directly on the exhaust gas (Kihara n.d.).Opacimeter uses the light transmission method, which gives an advantage over other systems to detect blue and white smoke of exhaust gases. The exhaust gas is drawn into a filter and the visible light from the source attenuate due to absorption and scattering. The concentration of the smoke is calculated using

Lambert-Beer equation. The result is expressed in percentage or as a coefficient.

2.5.1.3 Transmissometers

Transmissometers provides most reliable and obvious method of continuous monitor. It consist of light source mounted on one side of the duct/ chimney, transmitting visible light across a conduit towards a detector on the opposite side of the conduit. The beam is allowed to pass through the dust particulates to get absorbed and scatter light to cause changes in intensity of the received light. The changes in the intensity of the received light determines the dust concentration. The accuracy of these systems are maintained by keeping the optical surface clean (Clarke 1998) . Any dirt contaminating optical surface will increase apparent particulate level.

2.5.1.4 Smoke Density Monitors

Smoke density monitors are used in many heavy industries and mines where there is much dust in the air. This system essentially used to monitor smoke which is generated without significant amount of carbon monoxide, which is commonly monitored (E, Christophere & North 1995). It monitors smoke with less carbon monoxide which other systems cannot detect, which may generate thick smoke, choking smoking, without activation of conventional temperature of carbon monoxide sensor and alarm (E et al. 1995). The smoke sensor deployed is designed to identify the characteristic of smoke with the particle diameter within a specified range. It eliminates any dust and steam sensitivity and only detects smoke which is produced by a fire cause(Tanashi, Ryuichi & Yuki. 1998) .

2.5.2 Mobile Sensor Monitoring System

Recent applications use a smart sensor networking systems and wireless systems(Al-Ali, Zualkernan & Aloul 2010). These sensor network systems are based on a mobile sensor network (Varela, Paz-Lopez, Duro, Lopez-Pea & Gonzalez-Castano 2009). They are less expensive to implement and operate, as well as more flexible and scalable, and the unit can be placed on any moving device or worker on site (Al-Ali et al. 2010),(Varela et al. 2009), (Contreras, Morales, Vera, Cerda & Abarca 2012).With regards to implementation these network sensors are backed up by a software architecture to provide means to capture and integrate raw data from multiples heterogeneous sensors (Varela et al. 2009).This system type deploys light absorption method (Weibring, Edner, Svanberg, Cecchi, Pantani & Caltabiano 1998).It measures volcanic dust particulates, road dust, and industrial atmospheric mercury and hydrocarbon emission (H, K, A, S, L & W n.d.).This system type comes in many application purposes. One application of this system type is in underground mines. The device is carried by users without interfering with their duties. Users working in different locations and travel throughout the different routes and gives complete measures of the mine in any time of the day (Contreras et al. 2012).The other application is to monitor public areas. These mobile devices are mounted on a public transports such as buses to monitor certain areas where they assigned to operate on. The data collected is transferred on a internet protocol to the base station. It must be noted that the monitoring devices are owned by organizations purposely deployed to make future plans on keeping air quality healthy.

2.5.3 Image Processing Techniques

Previous work in the field was based upon fundamental optical theory of absorption, light scattering and light reflection which utilizes the image processing technique of using images. Due to the rapid development of digital technologies successful image processing monitoring systems were established. This has overcome problems encountered by satellite imaging having difficulty to obtain cloud free scenes. Numerous studies discussed the implantation of this system in Malaysia (Wong, MatJafri, Abdullah, Lim & Low 2007*a*),(Saleh et al. 2007),(Lim, MatJafri, Abdullah, Wong & Saleh 2006) . The studies on the system in Malaysia, showed that PM10 was linearly related to reflectance for band 1 and band 2, other studies also found that PM10 is linearly related to optical depth. Meaning reflectance is linear with the PM10.They simplified the data processing by using air quality concentration for analysis instead of using density (Wong et al. 2007*a*). This monitoring system was installed at Sains University in Malaysia to monitor particulate matter with diameter less than PM10. This system uses a surveillance camera, a Sun light as a light source for backscattering and reflection methods and it is connected to internet protocol. The IP camera is the air quality remote monitoring sensor designed to monitor particulates with diameter less than 10 micrometer. The camera used is a 0.3 mega pixel charge-coupled-Device CCD, allow the image data transfer over standard computer networks, internet (Wong et al. 2007*a*).

2.6 Conclusion

The rapid growth in population, urbanisation, industrialization and motorization have been the factors to excessive emissions of waste into the atmosphere. Air pollution is the major environmental concerns and threat to human health (Tudose, Patrascu, Voinescu, Tataroiu & Tapus 2011),(Ogawa, Yamamura & Ishda 2006). Since the evaluation of the status of the air quality is challenging (Hariharan 2010), the optical monitoring systems were developed and implemented. This idea is now improved with existing new technology , mobile sensor systems and image processing systems.

2.7 Chapter Summary

This chapter has discussed the health and safety problems associated with air pollution due to growth in population, urbanisation, industrialization and motorization. The discussion outlined the fundamental information the air pollution has on human health and introducing the monitoring systems developed based on various literatures. The examination and analysis carried out in the research will be reflected in the later chapters.

Chapter 3

Methodology

3.1 Chapter Overview

This chapter covers the research and development methodology required for development of the image processing monitoring system and examination of its performance. This chapter also discusses the risk and hazards associated with laser. Any task required for completion of each section are outlined.

3.2 Research and Development Methods

The research and development methodology specified herein is developed based on various literatures. The knowledge on previous work was used on how the entire project aim would be achieved. This has led to break down of major tasks. The development of the air particle monitoring system based on image processing technique suggested for the design and implementation of air pollution monitoring system, which can operate in any location and be able to process image frames in real time observation. The moving images of backscattering and reflection of the laser beam has to be processed to still images frames to determine the particulate concentration. The video recording state has to be sampled in seconds to monitor air quality for real-time observation.

The video recorded by the surveillance camera was to be stored in a server and automatically uploaded to a main frame to be converted by algorithm to picture frames. For this project experiment the video recorded was manually uploaded to a personal computer and converted to picture frames. The conversion was done to avoid the output of 'wmv file' from changing when the video frames processed using MATLAB algorithm. The variation in the output was thought to happen due to decoding codec that was randomising the decompression of the video frames.

At the hardware level, the system required a camera to record video, a laser and a personal computer to manipulate images for processing. The camera was to be connected to a computer with a suitable support software for resource management, network and device control.

The hardware layer must interface with the software layer to record videos and convert them to frames suitable for processing . In this section the system design allows the video recorded by the camera to be fed to the processing software. The software is to control the camera to retrieve videos at a sampling rate in seconds and temporally store them in a server for processing. The processed data is to be compared with a set concentration and if it exceeded the threshold it will set off a alarm. However, due to limited resources to autonomously operate the system, the data collection and processing has to be done manually based on the understanding from various literatures acknowledged in the research conducted.

3.3 Task Analysis

The project methodology was simplified to the following major steps.

- Investigation of system types based on optical theory of light absorption, backscattering and reflection methods.
- Investigation and implementation of image processing techniques.
- Investigation on laser and risk assessment.
- Investigation on design and implementation of suitable camera control.
- Design and implementation of a suitable software algorithm for processing recorded videos and data storage.

- Full system integration and testing.

The tasks identified were set as major components for system development and as guides for project progress. The following is the investigation of the details of each of the tasks and identifies any resources which are required for their completion.

3.3.1 Camera Application

The image processing monitoring system requires software to control the camera to record video at a designated sampling rate for continuous real time observation. An algorithm was to be developed using a software package for generating the unique processing mechanism. The algorithm has to be developed based on the fundamental image processing technique to process the images of the light absorption, light scattering and light reflection. A separate algorithm has to be developed to automatically to calibrate the camera in terms of the desired sampling rate.

3.3.2 Investigation on Light Sources

The system sensitivity to air borne microscopic particulates highly depends on light absorption, light scattering and light reflection. A suitable light source was investigated based on various literature of similar applications. For this project the proposed light source is a laser. In terms of its application two things were considered to be investigated, a laser dot and laser line characteristics, which is discussed in chapter 4. For the laser dot the investigation was to observe the dispersion caused by scattering on a black background, and laser line is to investigate the backscattering and reflection of the laser beam from dust particulates.

The laser selected was a laser pointer with normal operating voltage of 4.5 volts. The adjustment of the laser line was also considered to generate multi-laser lines, this is also explained in chapter 4.

3.3.3 Image Processing

The monitoring system required the implementation and development of a suitable image processing technique and algorithm. This section required suitable algorithm to process images of light scattering and reflection of the particulates captured by the camera. In the context of image processing it has to be noted that the images referred herein are of invisible microscopic dust particles. These images may have been corrupted by noise interference and camera light exposure. A software package is required to develop an algorithm that uses methods to improve the quality of the data. The method considered to improve the quality of the images were image frame integration to improve signal to noise ratio, normalizing to correlate changes of the brightness level of selected region, averaging to create stabilized image and reduce noise. An algorithm has to be developed using MATLAB to implement these methods to perform image enhancement and noise reduction.

Further investigation was conducted on data compression based on Discrete Cosine Transform (DCT)application. This application defines a input sample of a image , taken as a block at some point in time. The output vector from the transformation contains a transform coefficient(Leis 2011). The transformation matrix stores the coefficient , which are normally fixed. Upon investigation, it was discovered that DCT can be used to determine digital numbers of RGB from a image being separated into three different bands. These numbers can then be used to determine the atmospherics reflectance values of different bands, and then can be used in newly developed algorithm to determine PM10 concentration.

3.3.4 Recording and Storage Investigation

It has to be noted that the requirement of the project is to analyse microscopic dust particles. These dust particles are invisible, to determine their concentration more image frames are required. Therefore the filming of videos were considered to be the optimal selection method for data collection. It was investigated that with the available technology, the recording could be done automatically by an algorithm. With advanced wireless internet protocols the images can be transferred over a internet and downloaded to a server by a separately developed algorithm for storage and processing.

The images can be stored in either video file format or converted to still images and stored for processing. The conversion of the video file to still images can only be done if the processing unit and the algorithm's capability to handle the processing of a given data format is too large.

3.3.5 Testing

The testing of the image processing monitoring system include the hardware and the algorithm developed to process the images, discussed in section 3.3.3.

3.3.5.1 Hardware

At the hardware level the positioning of the camera and the laser has to be carefully chosen . The camera should be positioned in the direction of the column of dust particles. This is to insure that the backscattering and reflection of the laser beam from the dust particulates are all captured by the camera. A selected laser must be visible with sharp laser beam to scatter and reflect light from the dust particles. This laser has to be tested for two choices discussed in section 3.3.2 . The laser dot dispersion caused by scattering and laser line caused by backscattering and reflection from the dust particles.

3.3.5.2 Software

At the software level, an algorithm has to be developed to process the images recorded by the camera. The investigation was to determine suitable methods required for processed images without destroying information of the microscopic dust particles within the images. The identified processing methods are listed below.

- Conversion of moving image to still image.
- image frame Integration .
- Region selection and Image Normalization.
- Image Averaging .

- tolerance.

3.4 Assessment of Consequential Effects and Ethical Responsibilities

3.4.1 Sustainability

Engineers Australia's policy on sustainability is a professional practice by Institute of Engineers Australia Ref041 this framework provides a fundamental evaluation of socio-economic systems, and environmental and sustainable engineering in society. This project requires no manufacturing other than using the available resources. The use of this equipment is reflective of current sustainability regulations and guidelines.

3.4.2 Ethnical Responsibilities

The practice of professional responsibility as an engineer is outlined by, the Institute of Engineers Australia (Engineers Australia 2010) has set out four (4) ethical code of conducts. The first ethical code is a demonstration of integrity, this ethical code presents a guide to carefully assess any task before taking any actions. It allows engineers to fully become engaged in any given task and perform under no supervision. Also respect of others and their characters/genders equality is exhibited. The other ethical practice is competency, it allows engineers to maintain and develop lifelong knowledge and skills. Their practice must reflect competency objectively and to act on the basis of the adequate knowledge. The third ethical code of conduct emphasis on exercising leadership, it encourages engineers to uphold the reputation and trustworthiness of the practice of engineering. It supports and encourages engineers to interact with others from different backgrounds. It also encourages to communication of relevant information and effectively, and to consider dependency of others on work performed. The last ethical code of conduct is to promote sustainability, this allows engineers to effectively participate with community and other stakeholders. Engineers promote the health and safety and well being of the community and the environment. Any task performed has to be balanced with the needs of future generation.

3.4.3 Safety

The laser used in the development of the monitoring system was required to comply with the relevant Australian and New Zealand safety standards. When using the laser, caution must be taken to avoid any eye damage that could result in the breaching of safety regulations and permanent health effects.

3.4.4 Risk Assessment

This research project involved a experiment with a class 3R laser pointer (Previously class III). The activity required risk assessment of the laser. The risk assessment induction was conducted to made known to the hazards involved with the use of lasers . In this case the laser is operated in a box, class 3R warning tags were placed, At the entrance and on the experiment setup to warn other students using the same room. It is insured the laser is not taken t from the enclosed box and pointed at anyone in the room.

Table 3.1: Risk assessment for laser

Eye infection	Existing Control	Consequences	Probability
Eye injury	Enclosed box for experiment	Hospital	Rare
Sight	Enclosed box	No injury	Rare

Table 3.2: Risk Rating

Probability	Consequence				
	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
A (Almost certain)	M	L	L	L	L
B (Likely)	L	L	L	L	L
C (Possible)	L	M	L	L	L
D (Unlikely)	L	L	L	L	L
E (Rare)	L	L	L	L	L

Working with class 3R laser involved a potential for exposure to the laser beam, the significant concern is the potential damage to the retina. Most laser pointers are likely to cause permanent retinal damage. See Apendix C for more details.

3.5 Chapter Summary

The chapter covers the research and system development methodologies of the project. It outlined the specific tasks required for project completion. The individual components were identified for the project to commence. The risk assessment of the project was carried out in relation to the use of the laser. The risk assessment outlined several requirements on how the laser to be handled during experiment to avoid damage to eyes.

Chapter 4

Design and Implementation

4.1 Chapter Overiew

This chapter discusses the details of the system design and implementation of MATLAB algorithm based on the knowledge from literature reviewed in chapter 2 and details provided in methodology in chapter 3. The discussion here is based on image processing techniques investigated throughout the semester to develop a monitoring system to deploy backscattering and reflection methods . The algorithm developed is to process images of a recorded videos.

4.2 Ideal System Design Setup

The system design setup shown below is a model of a predicated system design that could be implemented in a practical setting. The surveillance camera, laser and a computer are the primary components of this system. This system can be autonomously controlled with more complex algorithm. This means the system could record videos and upload them onto a wireless internet protocol for processing. In this dissertation, the system under investigation investigated only involved the camera, laser module and image processing methods .

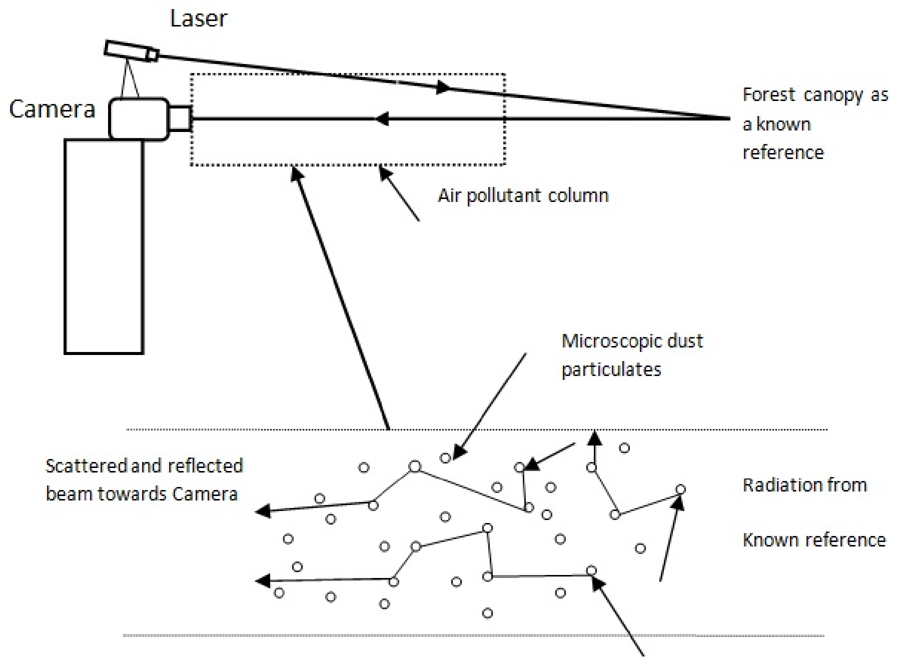

Figure 4.1: Ideal Setup of a Monitoring System

4.3 System Design and Operational Analysis

The system design in figure 4.1 is based on an understanding of how the backscattering and reflection of light behaves in air as discussed in previous chapters. The camera used was a webcam with a maximum resolution of 1080p.The camera itself is the remote air quality monitoring sensor. With the aid of laser beam the camera records the backscatters and reflection of the laser beam of the dust particles. In section 3.3.4 the major deliverable sections of the system design were identified. To test the system setup, design and operation a testing enclosure was built from a cardboard. The testing enclosure was constructed for two main reasons: Firstly for safety reasons for laser application, and secondly to block out all the external light sources from interfering with the experiment. The testing closer has a volume of 0.0216 m^3. The camera and the laser were setup inside the testing closer. The camera was stationed at one end of the testing closer to focused to a black background.

The visible laser has a typical wavelength range from 630-380 nm and was experimented with to test for laser dot dispersion cause by backscattering and laser line caused by the backscattering reflection. For the camera to capture the laser as a dot point on the background the laser was stationed on the same side with the camera and directed to where the camera focus was set. This method is to analyse laser dot dispersion caused by scattering. The laser line test was conducted by positioning the same laser on the wall between the camera and the black background . In this experiment a mirror was used to generate multiple laser lines. The multiple laser lines were projected across where column of dust particles was to be found. These laser lines appear visible when dust particles are present in the air. This method provided data that is easier to analyse the light intensity. As illustrated in figure 4.1, in practical sense the laser can be set at an angle so that the backscattered and reflectance from particulates are seen by the camera. This allows the laser beam to pass through a column of dust particulates. The airborne microscopic dust particles propagate randomly and backscatter and reflect the laser beam. The changes in the laser beam intensity captured by the camera gives an indication of dust particle concentration in the air.

The use of a laser allows the system to operate 24 hours/day to monitor air quality. The operation of the system is safe due to its specified risk assessment made aware to general public and the employees. The experiment setup for the system, indicated that the system is capable of monitoring dust particles in a specified volume.

4.4 Experiment

Table 4.1: Dust Samples in grams

Sample type	Weighed samples in grams			
Talcum powder	0	0.5	1	2

The experiment was conducted with the setup detailed in section 4.3. The equipment used in the experiment were, a webcam camera, visible red laser , dust samples ,personal computer and a fan. The webcam was connected to a personal computer and manually controlled to record the video. The first video recorded for each experiment, are dust free .These videos are recorded with the laser on, for 10 seconds. They are reference target to the experiments with the dust samples. When this videos were replayed, the laser beam is invisible. The next series of videos recorded after each reference target with different amounts of talcum powder samples being introduced into the test enclosure. The quantities of dust samples used in the experiments are given in table 4.1. When the dust sampled experiments were conducted the fan was used to keep the particles airborne. Each sample experiment was conducted one after the other when the dust from the previous experiment had enough time to settle. The time taken for each experiment varied depending on the quantity of dust and the time taken to introduce the dust samples into the test enclosure. The laser line appears visible in the dust samples, in these experiments the camera has to be stopped from recording when the laser lines diminishes. When the videos of the different dust samples were replayed they showed that the laser lines appeared thicker and brighter as the amount of dust samples increases. These files were manually downloaded onto personal computer for processing.

With the same experiment setup and dust samples repeated experiments were conducted to compare the results and to understand the process well enough to control the experiment. The only obvious improvement needed to consider here is to have a proper apparatus to pump the dust samples into the test closer at a same rate.

4.5 Image Processing Technique

A algorithm was developed using student version of MATLAB based on the projects requirements . With the understanding from various literature on image processing techniques, data from simple experiment was analysed using the following methods identified in section 3.3.4.e

- Conversion of moving image to still image.
- image frame Integration .
- Region selection and Image Normalization.
- Image Averaging .
- tolerance.

4.5.1 Pre-processing

In order to enhance the video images a pre-processing stages were implemented. The order in which the Pre-processing stages implemented were conversion of .wmv file to picture frames, image frame integration, region selection and image normalization, image averaging and setting tolerance. The webcam used can only record video in .wmv files and has maximum resolution of 1080p. The first problem encountered when processing the video file was, the MATLAB algorithm developed could not process the video recorded at 1080p. The experiment was repeated for 720p and the MATLAB algorithm was able to import and process the videos successfully. A "unit16" function in MATLAB was used to convert the images frames to a matrix of unsigned 16-bit integers. However, there was a problem with decoding wmv file. It was realised that the computer may have been randomising the decompression of the video frames and as a result the output matrix changes every time when the MATLAB algorithm is run.

The problem was eliminated by converting the video files to .jpg picture frames. It has to be noted that there are two sets of videos to process to analyse the particles concentration. The reference target video and the video of the dust particles reflectance. With the understanding of detecting particles with diameter of 10 micrometers and less with the low level resolution, the picture frames must be integrated . Frame integration utilises the redundant image information existing in the multiple image frames to help obtain the clear back ground, high contrast and clear image by improving the signal to noise ratio and by increasing the integration time.

In the process of manipulating the images' frames, the same regions were selected from both the controlled (Dust free) and dusty images by assigning (x, y) coordinates to be normalized. The normalization process modifies the distribution of pixel values of each image to make the whole data set statically compatible. This is prior to changes in brightness level in a selected region of interest. The selection of this reference is determined from a inspection of images. When considering the method to eliminate noise it was noted that the data of interest in the frames are of microscopic air borne particulates. Image averaging was the ideal method considered. Image averaging is a image processing technique that is used to enhance video images that have been corrupted by random noise. The MATLAB algorithm operates by computing the mean of the intensity values for each pixel position in a set of captured images from the same scene (Olympus America). In this images, there are stable signals and a random noise components. In the averaging processes, these signal components of the frames remain the same, but the noise component differs from one picture frame to another. Because the noise is random, it tends to cancel during the summation. The result is an enhanced signal component, while the noise component tends to be reduced by a factor approximately equal to the square root of the number of images averaged.

These images were separated into three different bands namely red, green and blue (RGB), and the matrix of this bands were determined. These matrices were are used to determine the reflectance of the different bands, and then used these matrix values to determine the changes in the light intensity to indicate the mass concentration of the air borne particles in the air. The example of the processed images for red band are shown in figure 4.1 and 4.2.

Averaging of N image frames

$$A(N,x,y) = \frac{1}{N} \times \sum_{i=1}^{n} I(i,x,y),$$

where N = image frames, $A(N,x,y)$ = Intensity values and (x,y) = pixel locations at cordinates.

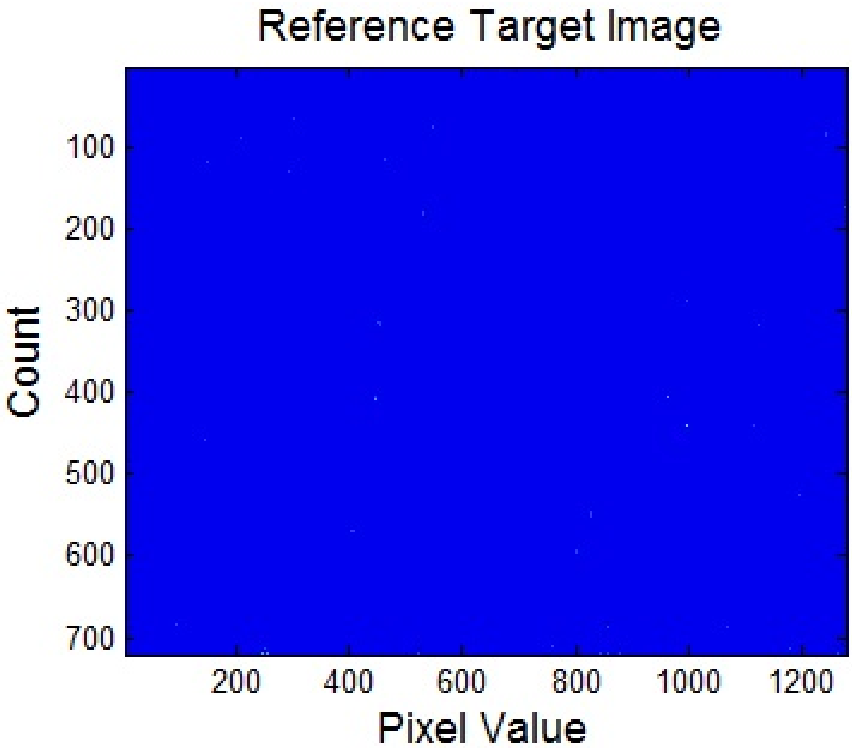

Figure 4.2: Averaged image of reference target (Dust free) for red band pixels

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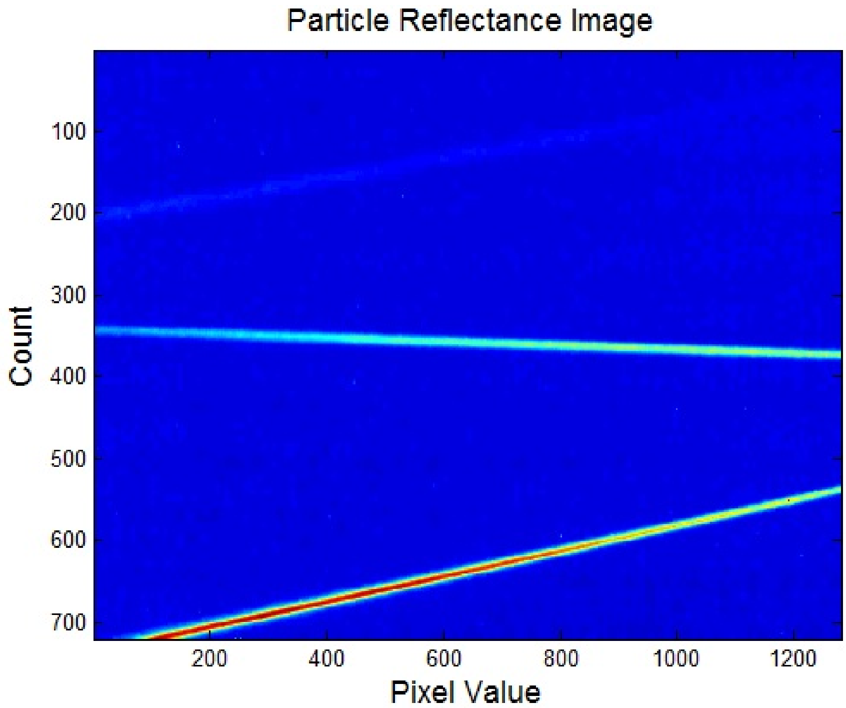

Figure 4.3: Averaged image of scattering and reflection for red band pixels

4.5.2 Dust Particle Concentraion

The matrix of the red band pixels for each the images of different quantity of dust samples from table 4.1 were determined. The pixel value of the image in figure 4.1 was set as a known reference for air quality . Reflectance of the particles recorded by the camera, example figure 4.2 was subtracted by the reflectance of the known reference for air quality to obtain the images of the particles concentration in the air, shown in figure 4.3.

$$R_p = R_s - R_r,$$

where R_p=reflectance recorded by the camera sensor, R_s=reflectance from a known reference and R_r=reflectance from air borne microscopic particles
The new matrix of the pixel determined is the R_p ,reflectance of the particle in the air.

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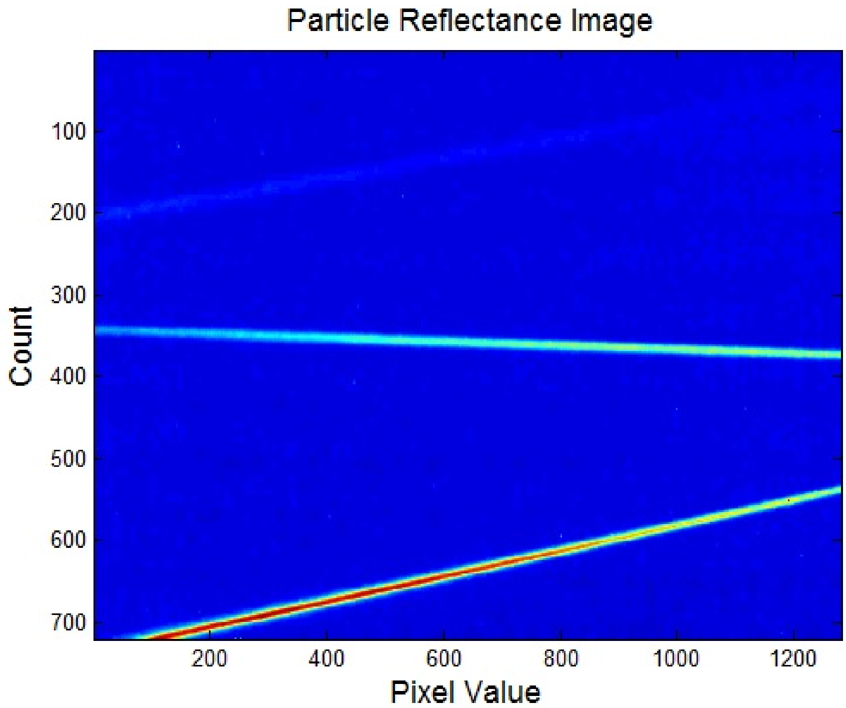

Figure 4.4: Reflectance from Air Particles

4.6 Chapter Summary

This chapter has discussed the signal processing methodology used by the dust monitoring system. The system design setup and the experiment conducted was discussed. Also the implementation of the algorithm developed from MATLAB and the stages of the processes to extract clear data from noise interference were detailed. It also detailed the determination of matrix values which were used in obtaining intensity of the particles in the air.

Chapter 5

Experiment Results and Performance Evaluation

5.1 Chapter Overview

This chapter evaluates the performance of the proposed dust monitoring system based on image processing techniques. The methodology and performance of the system were examined .This chapter also discussed the results obtained from the experiment to evaluate the performance of the system.

5.2 System Performance Evaluation and Methodology

The performance evaluation of the system discussed the suitability of the system and the proposed software. The system evaluation examines the real time observation capability, the sensor's sensitivity in detecting air borne particulates and compatibility evaluation of the software used for processing data.

The real time observation capability of the system, is the algorithm's dedication to the real- real-time aspect of image and video processing.

The evaluation on sensor's sensitivity in detecting air borne particulates, aims to evaluate the camera's sampling rate per frame under extreme conditions such as temperature and weather changes. To achieve best performance a high resolution camera, with an appropriate software algorithm is required to directly enable the camera to interface with a processor.

Compatibility evaluation of the Software aims to discuss the ability of the algorithm to directly interface with external devices and the microprocessor. It has to be noted that in the purpose of experimentation to guarantee the proposed system , student version MATLAB was the choice. The algorithm was purposely development only to process data. The result obtained from the experiment gave a positive outcome that the system can be design and implemented for practical use. The results obtained from the experiment are discussed in section 5.3. It is definite that the system can work autonomously with other software and complex algorithms.

Due to the lack of resources and timeframe the research methodologies detailed in chapter 3 were archived by operating the equipment manually. The results obtained were as expected and they are discussed in later sections.

5.3 Data analysis and Results

From the pre-processing of the still images discussed in chapter 4, a 720×1280 matrix of red bands were of interest . The experiment was repeated on different days to compare the results so that the conclusion can be made. These pixel values were plotted on histogram to visualize the changes in an intensity for the different quantities of the dust samples. Upon plotting of these pixel values a tolerance of 2+/- were applied to eliminate any background intensities. The intensity plots are shown in figures 5.1,5.3,5.5 and 5.7. A pixel value for each histograms were determined. These pixel values were plotted against the mass concentration calculated in equation 5.1.

$$Mass\ Concentration = \frac{Mass}{Volume} \tag{5.1}$$

The idea of using mass concentration was from the logic that the dust samples introduced into the testing enclosure did not fully occupied the volume, some settled as soon as they were pumped in. The correlation interpretation of line of best fit were plotted to determine the correlation between the light intensities and the dust concentrations. The linear correlation for these two sets of data are shown in figures 5.2, 5.4, 5.6 and 5.8. Each of these results are discussed in detail in each subsections below.

The average squared (mean square) error over N points is:

$$E(\varepsilon^2) = \frac{1}{N}\sum_N (y_d - b_x)^2,$$

where N =Number of points on (x,y) cordinate, E = is the error and yd are the points, bx are points on the line of bestfit

5.3.1 Result of Experiment on day 1

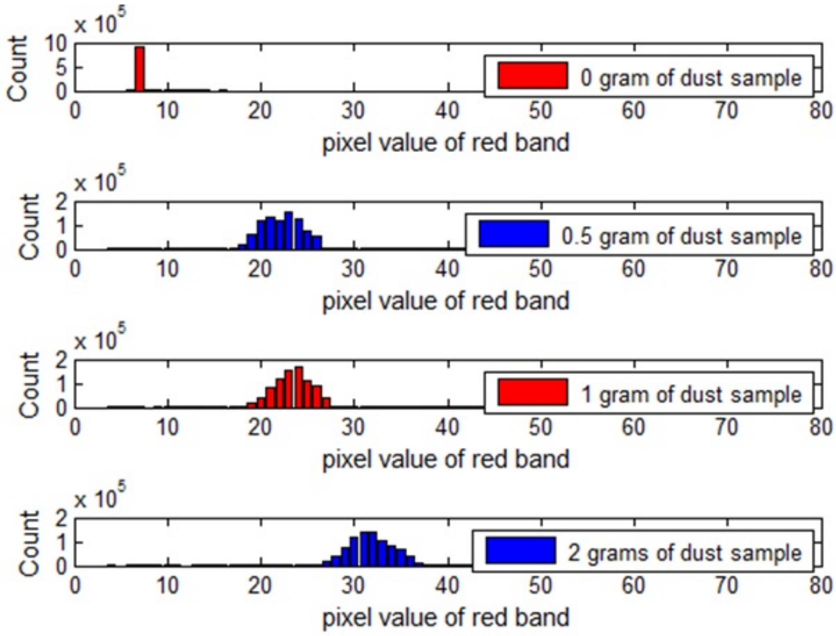

Figure 5.1: Histogram of the backscattering and reflection of particles from two laser lines for experiment in day1.

The histogram in figure 5.1 is a result of two laser lines generated by reflecting laser beam on two plane mirrors. The analysis of this graph is to visually observe the changes in light intensity in different dust concentrations. As it can be seen from the histograms the light intensity changes with different dust concentrations. Table 1 provides the pixel values obtained from the histograms.

Table 5.1: Parameter Experiment 1

Volume in meter	Error coefficient	Dust Sample in grams	Mass Concentration	Pixel Values
0.0216 m^3	3.3269	0	01	7
		0.5	23.15	23
		1	46	24
		2	92.59	31

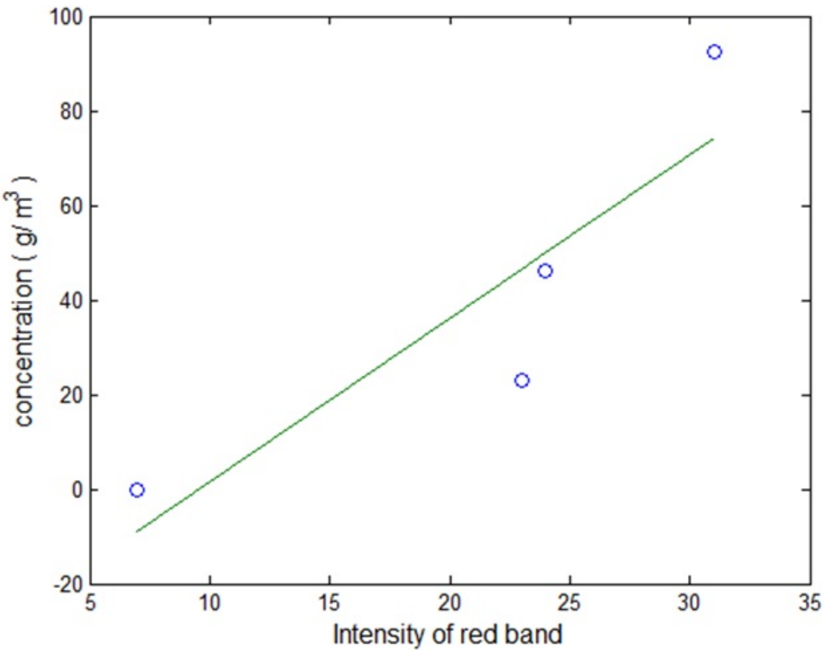

Figure 5.2: The correlation interpreted as a line of best fit. The measured points are shown as "o" and the lines shows the approximation in the (x, y) plane. This correlation is for laser producing one laser line.

The intensity verses dust concentration graph for histograms in figure 5.1 was plotted to determine the linear relationship of the pixel values and dust concentration as shown in figure 5.2. The aim is to compare the results of the repeated experiments to investigate on their linear relationship.

5.3.2 Result of Experiment on day 2

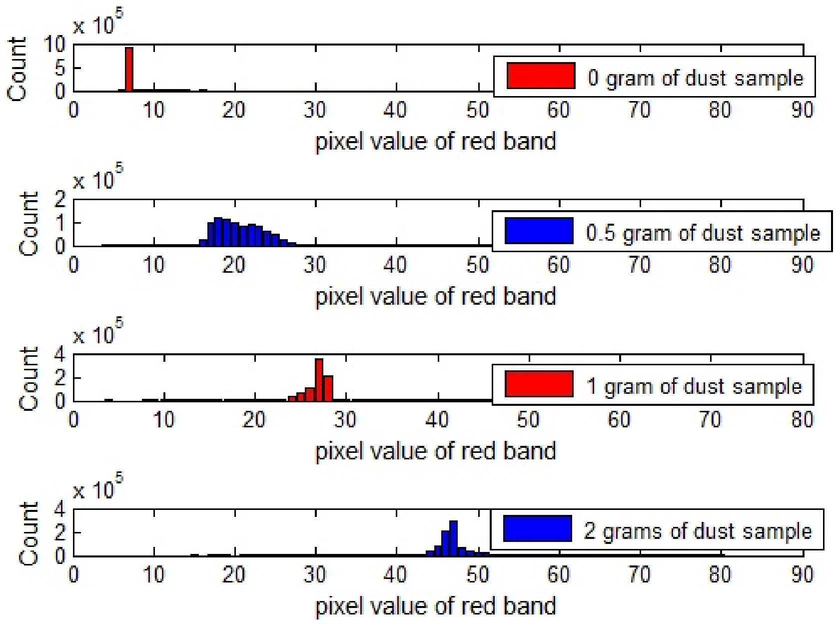

Figure 5.3: Histogram of the backscattering and reflection of particles from two laser lines for experiment in day2.

The histogram in figure 5.3 is a repeated experiment of figure 5.1 in day two. This experiment was conducted with the same quantities of dust samples and the experiment setting . The results varies from each other, this can be pictured from the histograms above and the intensity values provided in table 1 and 2.

Table 5.2: Parameter Experiment 2

Volume in meter	Error coefficient	Dust Sample in grams	Mass Concentration	Pixel Values
0.0216 m^3	0.017	0	0l	7
		0.5	23.15	18
		1	46	27
		2	92.59	47

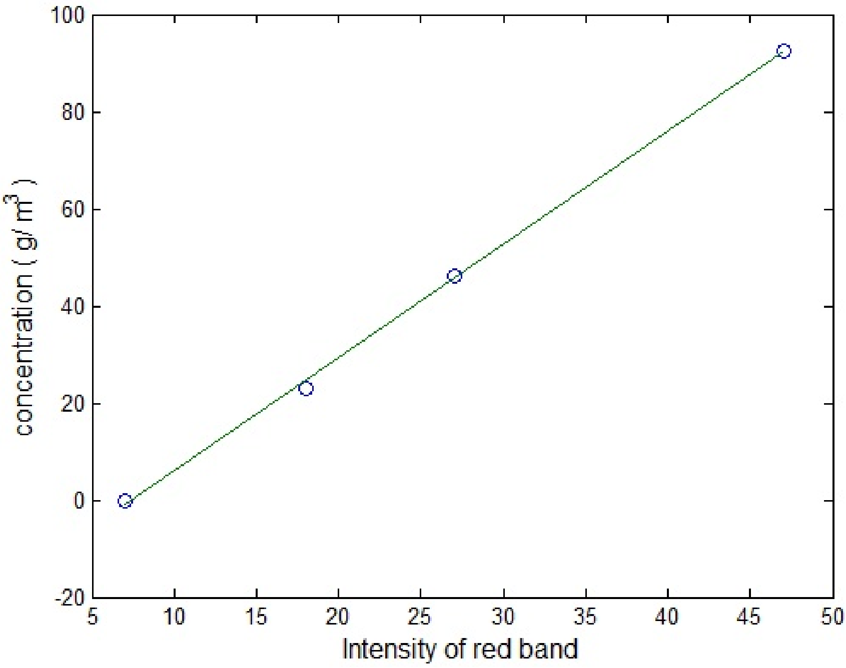

Figure 5.4: The correlation interpreted as a line of best fit. The measured points are shown as "o" and the lines shows the approximation in the (x, y) plane.

The light intensity values and the dust concentrations of the experiment in day two showed that these two data sets are linearly correlated. There are many factors that had a influence on the results obtained, such as, temperature, noise and handing of the experiment and others. The readers have to be informed that this experiment was manually conducted with no proper apparatus for pumping dust samples.

5.3.3 Result of Experiment on day 3

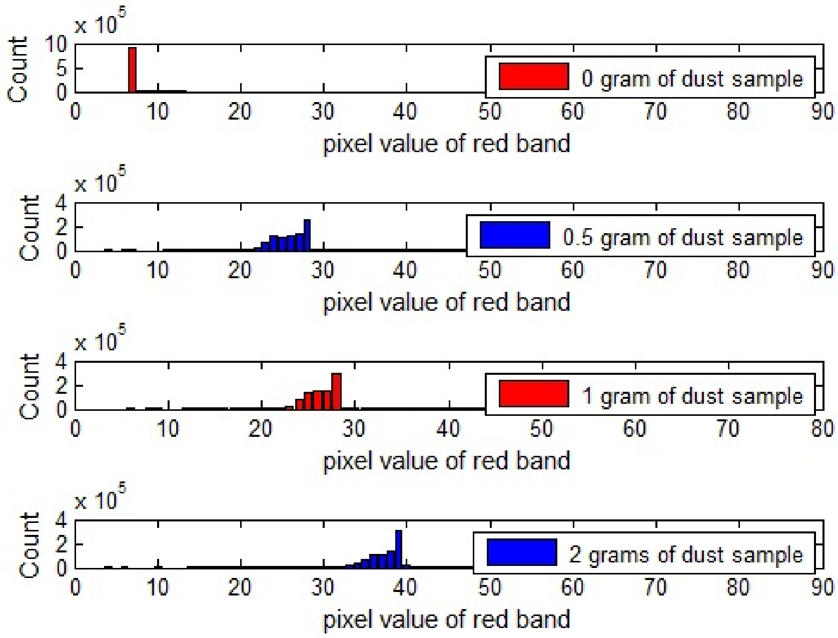

Figure 5.5: The pixel histogram of the scattering and reflection of particles from two laser lines for third experiment.

Upon comparing the experiment conducted on day three to experiments on day one and two the results varies in terms of pixel values for same qualities of dust samples. It is visually observable from the three histograms above that they are different. Let us look at an example to discuss the differences in pixel values, for 1 gram of dust sample in day one experiment the pixel value is 24, in day two is 27 and in day three is 28. This values are given in the tables.

Table 5.3: Parameter Experiment 3

Volume in meter	Error coefficient	Dust Sample in grams	Mass Concentration	Pixel Values
0.0216 m^3	3.3269	0	01	7
		0.5	23.15	28
		1	46	28
		2	92.59	39

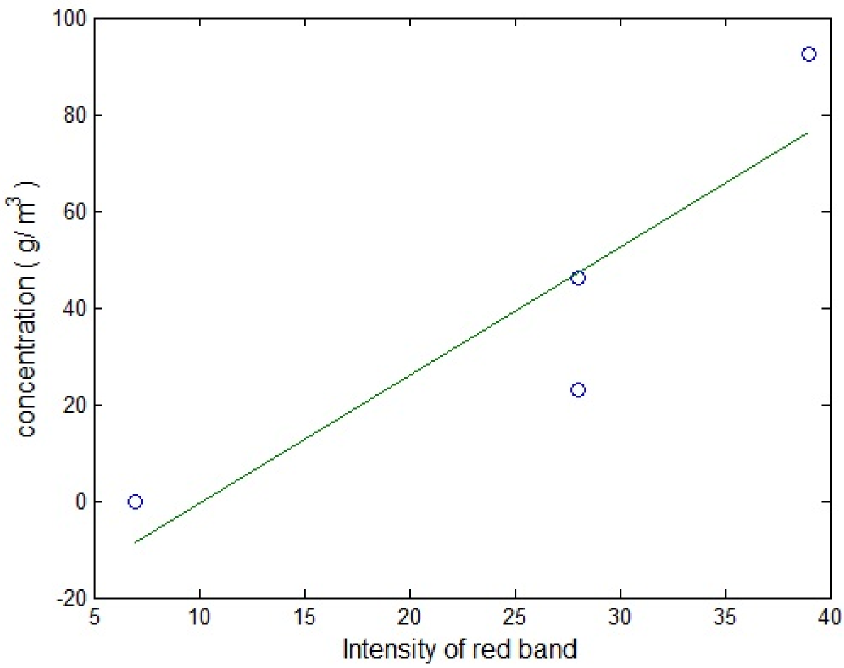

Figure 5.6: The correlation interpreted as a line of best fit. The measured points are shown as "o" and the lines shows the approximation in the (x, y) plane.

It can be noted from the linear relationship plot that these three experiment results are not the same. Comparison of the calculated points and the line of best fit in each case for an error. In the tables provided the error calculated showed that the experiment can be controlled to minimize the error and make it as small as possible. However, there would be still variation in error even if it is kept minimum.

5.3.4 Result of Final Experiment

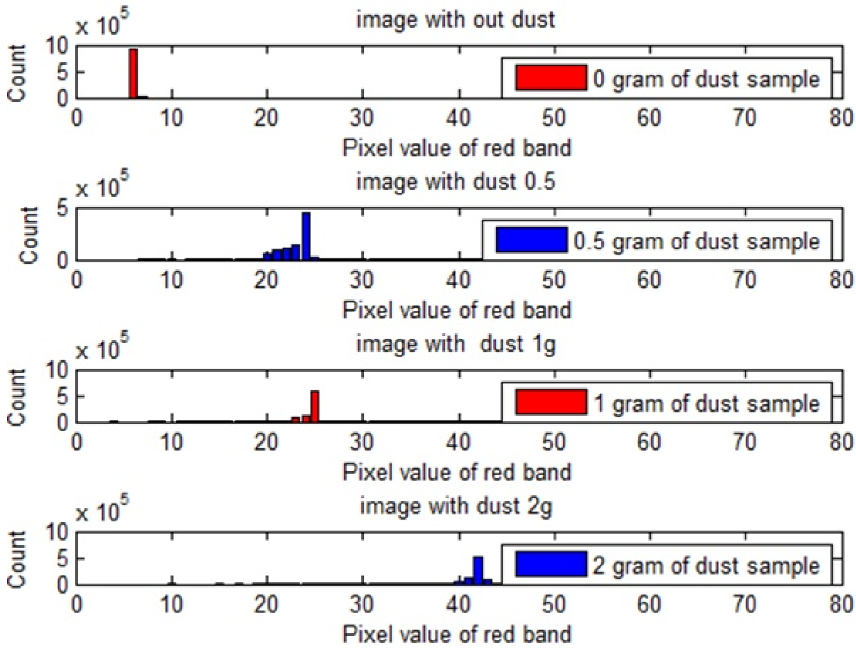

Figure 5.7: The final pixel histogram of the scattering and reflection of particles from one laser line .

The histogram in figure 5.7 is for single laser line, obtained from the conditions as the four previous experiments. The laser was moved accidentally in the process of repeated testing. This result was included in this dissertation to compare it with the multi-laser lines . Upon comparison it is concluded that the system can still perform as required with signal laser beam.

Table 5.4: Parameter Experiment 4

Volume in meter	Error coefficient	Dust Sample in grams	Mass Concentration	Pixel Values
0.1806 m^3	3.3269	0	01	6
		0.5	23.15	24
		1	46	25
		2	92.59	42

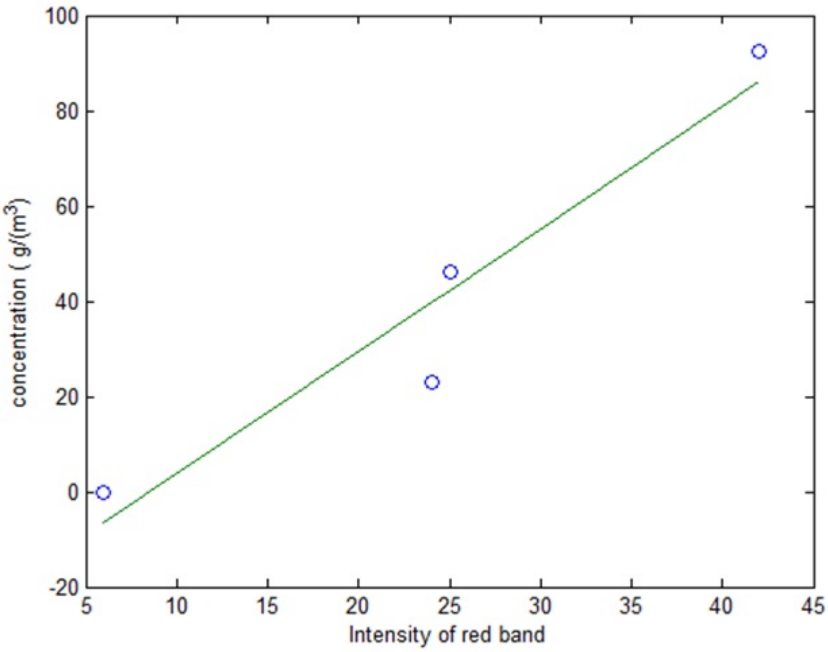

Figure 5.8: The correlation interpreted as a line of best fit. The measured points are shown as "o" and the lines shows the approximation in the (x, y) plane. This correlation is for laser producing one laser lines.es

The linear relationship of single laser line in figure 5.8 has a average square error of 0.1806. This shows that the system can still detect particles with single laser beam. The results obtained here is of the same quality as in multi laser lines.

5.4 Result discussion

The results shown in this chapter are indicative of the viability of the robust air particle monitoring system based on image processing technique. In order to gain an understanding of this monitoring system, it requires comparisons with existing image processing techniques, particularly satellite remote sensing systems. The aim is to monitor microscopic airborne particulates. Although there were variation in the results obtained from the repeated experiments, the system performance has shown are greater potential in air quality monitoring .

The system designed here has proven to exhibit excellent performance in detecting backscattering and reflection of laser beam from microscopic particles in the air. The system can be designed and implemented at a low cost . Therefore air pollution monitoring systems based on image processing technique can be developed to be used at residential and in public areas.

Although the image processing technique exhibits excellent characteristics in processing images, it does have some disadvantages . A obvious disadvantage of this technique is the noise interference , which has to be filtered using suitable method without destroying valuable information.

However, to design and implement this system it only requires a camera, a computer, light source and software package. The Logitech webcam with maximum resolution of 1080p operated at 720p performed well. The red laser module also worked well in terms of backscattering and reflection of beam from the dust particles.

In addition, the image processing algorithm performed well. The images were successfully imported and processed to pixel values. These pixel values were then used to determined the particle concentration.

5.5 Chapter Summary

In this chapter, the system performance and the experiments results were discussed. The system proposed proved to be successful . The outcomes of the experiments recommends that with better resources the results would have been beyond what has been achieved.

Chapter 6

Conclusion

6.1 Chapter Overview

This chapter outlines the recommendation for further work and research for remaining part of the project to fully analyse the air quality.

6.2 Recommendation

The proposed design for air particle monitoring using image processing technique was guaranteed a suitable system for use in air particle monitoring application. The results showed that the use of webcam, laser and MATLAB algorithm provides a fully functional monitoring system to detect dust particles at a low cost. The system was operated manually and shown to work well as an remote sensor.

The evaluation of the performance outcomes indicated that with a quality camera and other software that directly interface with processor such C/C++ would fully interface the camera with the processor to process the data at moving sampling rate. The problem encountered in decompressing frames would have been overcome by processing the frames at average moving rate. It is recommended that the algorithm be developed in software that can autonomously control the whole system including storage of data and processing of the data.

6.3 Future Research and Development

The completion of this project leaves other major sections for further work. The further work includes:

- investigation on how to determine particle sizes.
- analysis of the system's performance and sensitivity to detect microscopic dust particles.
- Suitable method to calibrate camera.
- Investigation on how much light is required according to the volume percentage of dust present
- Investigation on what particle sizes to be detected.

To successfully implement this system, several improvements which were identified outside the scope of this project may be investigated. The development of the wireless to allow data transfer over a internet protocol, which provides real time observation and image processing. This would make it possible to monitor real time microscopic dust particles at multi locations. The system sensitivity could be furthered developed to detect particles sizes with 10 micrometers and less. Furthermore, the camera may be automatically calibrated to its known reference target at the end of every sampling rate. The hardware and software selection were not investigated in detail when evaluating the performance as being not part of this project. However, it was discovered that there are other software with capabilities that may be suitable for this project requirement and a HD camera for particle detection. The comparison testing for different hardware and software has not been done, as this is not part of project requirement.

6.4 In Summary

This project proposes a system model for continuous monitoring of air particles using image processing technique and laser beam application utilising backscattering and reflection methods. This system can provide the fundamental idea for further development and applications of this system.

The method involved in developing the air particle monitoring system using image processing technique, include the investigation of current literatures on monitoring systems based on backscattering and reflection methods. The understanding of this systems create a knowledge to investigate on image processing technique application. The suitability of a particles detection was enhanced by frame integration. The data quality depends on camera's resolution used in capturing images of microscopic air borne particulates . The image processing technique discussed herein demonstrates the monitoring system proposed .The system designed was able to perform as required and provided significant detailed information.

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Appendix A

Project Specification

ENG 4111/4112 Research Project

PROJECT SPECIFICATION

For: **Newman Kauori Sana**

Topic: Air Particle Monitoring using Image Processing

Supervisor: Dr John Leis

Sponsorship: Faculty of Engineering and Surveying

Project Aim: The aim of this project is to develop and compare two different types of dust detection and measurement methods. An initial aim is to research optical/-electronic methods using image processing approaches, whereby backscatter of a light source is imaged on a camera, and particle counts are measured. Another approach is to measure the change in absorption of a beam over time, rather than the absolute absorption. The focus of the investigation is on optical methods using image processing to analyse the backscatter. The design aim is for a portable, low cost sensor which does not need calibration against a known reference.

Programme: Issue B, 26th March 2013

1. Research the background information on standards for dust monitoring used in Australia and internationally.

2. Research existing methods based on light absorption, light scattering and light reflection from particles in the air.

3. Research and examine backscattering and reflection method of infrared radiation from particles of dust.

4. Investigate suitability of camera types for image processing using infrared wavelengths.

5. Investigate image processing algorithms which may be suitable for analysing the infrared images and count particles present.

6. Develop a prototype measuring system to evaluate the concept. Thus may use off- the-shelf cameras and infrared sources, or other means.

As time and resources permit:

1. Analyse the performance and sensitivity of the device; how it will be calibrated, how much light is required according to the volume percentage of dust present, and what particle sizes are detectable. Calibration of the dust levels would need to be considered at this stage.

AGREED:

Student Name: Newman Sana
Date:

Supervisor Name: John Leis
Date:

Examiner/Co-Examiner:
Date:

Appendix B

MATLAB Code for Image Processing

```
% ENG 4111 & 4112 Research Project
% TITLE: AIR PARTICLE MONITORING using IMAGE PROCESSING
clc
clear all
close all

%  Importing and integration of 2 grams of dust sample
g=0:0.01:1;

ND = zeros(720,1280,3);

for n= 1:36;
    filename=num2str(n);
    if length(filename)<2;
        filename(2)=filename(1);
        filename(1)='0';
    end
    filename={['ND ',filename,'.jpg']};
    filename=filename{1};

Ls=uint16(imread(filename));% read image in the file


 ND=Ls+uint16(n);

end



% Importing and integration of 0.5 grams of dust sample

 D1= zeros(720,1280,3);

for n1= 1:36;
    filename1=num2str(n1);
    if length(filename1)<2
        filename1(2)=filename1(1);
```

```
        filename1(1)='0';
    end
    filename1={['D0_5 ',filename1,'.jpg']};
    filename1=filename1{1};

Ls1=uint16(imread(filename1));% read image in the file


 D1=Ls1+uint16(D1);


end
figure(20);
RchannelD1=D1(:,:,1);
imagesc(D1);




D2= zeros(720,1280,3);



for n2= 1:36;
    filename2=num2str(n2);
    if length(filename2)<2;
        filename2(2)=filename2(1);
        filename2(1)='0';
    end
    filename2={['D_1 ',filename2,'.jpg']};
    filename2=filename2{1};

Ls2=uint16(imread(filename2));% read image in the file


 D2=Ls2+uint16(D2);


end




% Importing and integration of 2 grams of dust sample
```

```
D3= zeros(720,1280,3);

for n3= 1:50
    filename3=num2str(n3);
    if length(filename3)<2
        filename3(2)=filename3(1);
        filename3(1)='0';
    end
    filename3={['D_2 ',filename3,'.jpg']};
    filename3=filename3{1};

Ls3=uint16(imread(filename3));% read image in the file


 D3=Ls3+uint16(D3);

end

%%




% Normalization of 0 gram of dust sample image



NoDust=sum(ND(1:600,400:600,1));% region to calculate


Dust1=sum(D1(1:600,400:600,1));% region to calculate


%
DV1=Dust1/NoDust;% Normalise


ScaleimND1=DV1*ND;% matching intensity


ScaleimD1=DV1*D1;% matching intensity


dataaVND1=ScaleimND1./(n);%average the frame for image with out dust
```

```
RchanneldataaVND1=dataaVND1(:,:,1);%red band for no dust
GchanneldataaVND1=dataaVND1(:,:,2);%Green band for no dust
figure(1);
%subplot(2,1,1)
imagesc(RchanneldataaVND1);
ylabel('Count','fontsize',13);
xlabel('Pixel Value','fontsize',13);
title(' Reference Target Image','fontsize',13);



dataaVD1=ScaleimD1./(n1);%average the frame for image with dust
dataaVD1 = uint16(dataaVD1);


AtDiff1 = dataaVD1-dataaVND1; %

%%
%Normalization of 0.5 gram of dust sample image

RchanneldataaVND1 = RchanneldataaVND1(RchanneldataaVND1> 2); % tolarence +/-
    2 red band
GchanneldataaVND1 = GchanneldataaVND1(GchanneldataaVND1> 2);% tolarence +/-
    green band
%figure(2);
yNDR = hist(RchanneldataaVND1,0:255);% hist command for histgram plot for red
    band
[maxnumyNDR posyNDR]=max(yNDR); % Deter mine pixel value for red band

yNDG = hist(GchanneldataaVND1,0:255);% hist command for histgram plot for red
    band
[maxnumyNDG posyNDG]=max(yNDG);% Deter mine pixel value for green band




% % Pure reflectnace
RchannelAtDiff1=AtDiff1(:,:,1); % separate imge in to red band
```

```
RchanneldataaVDR1 = RchannelAtDiff1(RchannelAtDiff1> 2);% tolarence +/- 2 red
    band

GchannelAtDiff1=AtDiff1(:,:,1);% separate imge in to green band
GchanneldataaVDG1 = GchannelAtDiff1(GchannelAtDiff1> 2);% tolarence +/- 2
    grren band

yDR1 = hist(RchanneldataaVDR1,0:255);% hist command for histogram plot for
    red band
[maxnumyDR1 posyDR1]=max(yDR1);%determines pixel value of red band

yDG1 = hist(GchanneldataaVDG1,0:255);% hist command for histogram plot for
    green band
[maxnumyDG1 posyDG1]=max(yDG1);%determines pixel value of green band


figure(4);
imagesc(RchannelAtDiff1);% image plot for 0.5 gram of dust sample
title('image with dust 0.5 g')

%%
%Normalization of 1 gram of dust sample image

NoDust=sum(ND(1:600,400:600,1));% region to calculate

Dust2=sum(D2(1:600,400:600,1));% region to calculate

DV2=Dust2/NoDust;% Normalise

ScaleimND2=DV2*ND(:,:,1);% matching intensity

ScaleimD2=DV2*D2(:,:,1);% matching intensity

dataaVND2=ScaleimND2./(n);%average the frame for image with out dust


dataaVD2=ScaleimD2./(n2);%average the frame for image with dust
dataaV2D2 = uint16(dataaVD2);% Conversion of matixe to unsigned 16bits
    integers
```

```
AtDiff2 = dataaVD2-dataaVND2; % Detremoiention of particles reflectance


% Pure reflectnace
RchannelAtDiff2=AtDiff2(:,:,1); % seperation of red band from image
RchanneldataaVDR2 = RchannelAtDiff2(RchannelAtDiff2> 2);% tolarence of +/- 2


GchannelAtDiff2=AtDiff2(:,:,1);% % seperation of green band from image
GchanneldataaVDG2 = GchannelAtDiff2(GchannelAtDiff2> 2);%tolarence of +/- 2


yDR2 = hist(RchanneldataaVDR2,0:255);% his t comand to determine matrix for
    histogram plot
[maxnumyDR2 posyDR2]=max(yDR2);% determine pixel of red band

yDG2 = hist(GchanneldataaVDG2,0:255);%his t comand to determine matrix for
    histogram plot
[maxnumyDG2 posyDG2]=max(yDG2);% Determine pixel value

figure(6);
imagesc(RchannelAtDiff2);% Image plot of 1 grams of dust sample

%%

%Normalization of 2 grams of dust sample image_

NoDust=sum(ND(1:600,400:600,1));% region to calculate

Dust3=sum(D3(1:600,400:600,1));% region to calculate

DV3=Dust3/NoDust;% Normalise

ScaleimND3=DV3*ND(:,:,1);% matching intensity

ScaleimD3=DV3*D3(:,:,1);% matching intensity

dataaVND3=ScaleimND3./(n);%average the frame for image with out dust
```

```
dataaVD3=ScaleimD3./(n3);%average the frame for image with dust
dataaVD3 = uint16(dataaVD3); % Conversion of matrix to 16bits integers

AtDiff3 = dataaVD3-dataaVND3; % partyicles reflectance for 2 grams of dust
    samples



% % Pure reflectnace of 2 grams
RchannelAtDiff3=AtDiff3(:,:,1);% red band seration from image
RchanneldataaVDR3 = RchannelAtDiff3(RchannelAtDiff3> 2); %+/- 2 tolarenace

GchannelAtDiff3=AtDiff3(:,:,1);% green band saperation
GchanneldataaVDG3 = GchannelAtDiff3(GchannelAtDiff3> 2);%+/- 2 tolarenace


yDR3 = hist(RchanneldataaVDR3,0:255);% hist command for histogram plot
[maxnumyDR3 posyDR3]=max(yDR3);% determine pixel value

yDG3 = hist(GchanneldataaVDG3,0:255);%hist command for histogram plot
[maxnumyDG3 posyDG3]=max(yDG3);% determine pixel value

figure(8);
imagesc(RchannelAtDiff3);

%%
%Histogram plot for read bands

%0 gram
figure(9)

subplot(4,1,1)
bar(yNDR(1:80),'r');
xlabel('pixel value of red band' ,'fontsize',11');
ylabel('Count','fontsize',11);
legend(' 0 gram of dust sample','fontsize',11);
```

```
%0.5 gram

subplot(4,1,2)
bar(yDR1(1:80),'b');
xlabel('pixel value of red band','fontsize',11);
ylabel('Count','fontsize',11);
legend(' 0.5 gram of dust sample','fontsize',11);


%1 grams
subplot(4,1,3)
bar(yDR2(1:70),'r');
xlabel('pixel value of red band','fontsize',11);
ylabel('Count','fontsize',11);
legend(' 1 gram of dust sample','fontsize',11);

% 2 grams

subplot(4,1,4)
bar(yDR3(1:80),'b');
xlabel('pixel value of red band','fontsize',11);
ylabel('Count','fontsize',11);
 legend(' 2 grams of dust sample','fontsize',11);




figure(10)
intensityNOR=([7 23 24 31]);
 yR=([0 .5 1 2]);
p = polyfit(intensityNOR,yR,1);
f = polyval(p,intensityNOR);
plot(intensityNOR,yR,'o',intensityNOR,f,'-');
xlabel('Intensity of red band');
ylabel('amount ( in grams)');
axis([0 40 -1 3]) ;
```

```
%%
%
% %___________ GREEN BAND _____________________________

figure(11)

subplot(4,1,1)
bar(yNDG,'g');
title('image with NO dust ');
xlabel('Intensity of red band');
ylabel('Count');
xlim([0 100])


subplot(4,1,2)
bar(yDG1,'g');
title('image with dust 0.5g');
xlabel('Intensity of red band');
ylabel('Count');
xlim([0 100])



subplot(4,1,3)
bar(yDG2,'g');
title('image with dust 1g');
xlabel('Intensity of red band');
ylabel('Count');
xlim([0 100])


subplot(4,1,4)
bar(yDG3,'g');
title('image with dust 2 g');
xlabel('Intensity of red band');
ylabel('Count');
xlim([0 100])
```

```
figure(12)
intensityNOG=([7 18 27 47]);
%
 yg=([0 .5 1 2]);
%

p = polyfit(intensityNOR,yg,1);
f = polyval(p,intensityNOG);
plot(intensityNOG,yg,'o',intensityNOG,f,'-');
xlabel('Intensity of red band');
ylabel('amount ( in grams)');
axis([0 40 -1 3]) ;

%%

% Correlation polt of intensity versus concentration for red band

figure(13)
intensityNOR=([7 18 27 47]);
%
 yg=([0 23.15 46 92.59]);
%

p = polyfit(intensityNOR,yg,1);
f = polyval(p,intensityNOR);
erro =( (yg-f).^2)./4;
plot(intensityNOG,yg,'o',intensityNOG,f,'-');
xlabel('Intensity of red band','fontsize',12);
ylabel('concentration ( g/ m^3 )','fontsize',12);
%grid on

%%

%Red band of images
figure(14);
RchannelD3=D3(:,:,1);
RchannelD3 = RchannelD3(RchannelD3> 2);
imagesc(RchannelD3);
```

```
figure(15);
RchannelDust3=Dust3(:,:,1);
RchannelDust3= RchannelDust3(RchannelDust3> 2);
imagesc(Dust3);
title('Image before filtering');


figure(16);
RchanneldataaVD3=dataaVD3(:,:,1);
RchanneldataaVD3= RchanneldataaVD3(RchanneldataaVD3> 2);
imagesc(dataaVD3);
ylabel('Count','fontsize',13);
xlabel('Pixel Value','fontsize',13);
title(' Particle Reflectance Image','fontsize',13);


figure(17);
RchannelAtDiff3=AtDiff3(:,:,1);
RchannelAtDiff3= RchannelAtDiff3(RchannelAtDiff3> 2);
imagesc(AtDiff3);

ylabel('Count','fontsize',13);
xlabel('Pixel Value','fontsize',13);
title(' Particle Rflectance Image','fontsize',13);
```

Appendix C

Risk Assessment

University of Southern Queensland

Risk Management Plan

A **hazard** is something with the potential to cause harm.

Risk is the likelihood that a harmful consequence (death, injury or illness) might result when exposed to the hazard.

Risk assessment: The process of evaluating the severity of a risk, for the purposes of prioritising and taking action to control the risk. Assessing a risk involves considering the likelihood of harm arising from a hazard and the severity of the consequences that could result.

Table C.1: Risk Assessment Plan

Date: **29/08/2013**	**Faculty/Department:** FACULTY of HEALTH, ENGINEERING AND SCIENCE, MECH & ELEC ENG	**Assessment completed by:** Newman Sana John Leis	**Contact number:** 0402703766
What is the task? Research experiment involving laser pointer's beam for image processing		**Location where task is being conducted:** Z320.1 Laboratory	
Why is the task being conducted? To experiment how dust particles backscatter and reflect laser beam.			
What are the nominal conditions?			
Personnel Newman Sana John Leis	**Equipment** Class 3R Laser pointer, DC power supply, camera and fan.	**Environment** Unsupervised but controlled laboratory	**Other**

Table C.2: Risk Assessment Plan

Briefly explain the procedure for this task (including reference to other procedures)

The experiment involves a class 3R laser pointer (Old system class III) ,webcam and a fan. The typical wavelength of the laser range from 630nm to 680nm, power output range from 1mW to less than 5 mW. The laser's normal operating voltage is 4.5 volt supplied from batteries. The laser is connected to an adjustable DC power supply set at 4.5 volts.

Reference is made to :

http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/685/Laser_classification_and_potential_hazards.pdf

http://www.ehs.utoronto.ca/services/laserhome/laserpg/laserptr.htm

http://www.csu.edu.au/acad_sec/committees/radiation/faq/visible_light_lasers.htm

Safety Recommendations for Laser Pointers - s\lasersafety\Safety Recommendations for Laser Pointers.doc (from Princeton EHS)

Australian Standard AS2211.1 - Safety of Laser Products Part 1 Equipment Classification, Requirements & Users Guide
AS/NZS IEC 60825:2011 Safety of Laser Products(Updates AS2211)

Table C.3: Risk Ratinge

Probability	Consequence				
	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
A (Almost certain)	M	L	L	L	L
B (Likely)	L	L	L	L	L
C (Possible)	L	M	L	L	L
D (Unlikely)	L	L	L	L	L
E (Rare)	L	L	L	L	L

Table C.4: Recommended Action Giude

Abbrev	Action Level	Descriptor
E	Extreme	The proposed task or process activity MUST NOT proceed until the supervisor has reviewed the task or process design and risk controls. They must take steps to firstly eliminate the risk and if this is not possible to introduce measures to control the risk by reducing the level of risk to the lowest level achievable. In the case of an existing hazard that is identified, controls must be put in place immediately.
H	High	Urgent action is required to eliminate or reduce the foreseeable risk arising from the task or process. The supervisor must be made aware of the hazard. However, the supervisor may give special permission for staff to undertake some high risk activities provided that system of work is clearly documented, specific training has been given in the required procedure and an adequate review of the task and risk controls has been undertaken. This includes providing risk controls identified in Legislation, Australian Standards, Codes of Practice etc.* A detailed Standard Operating Procedure is required. * and monitoring of its implementation must occur to check the risk level
M	Moderate	Action to eliminate or reduce the risk is required within a specified period. The supervisor should approve all moderate risk task or process activities. A Standard Operating Procedure or Safe Work Method statement is required
L	Low	Manage by routine procedures.