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A Study on Environmental Micro-Dust Level Detection and Remote Monitoring of Outdoor Facilities

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Abstract

The rapid development in modern industrialization pollutant the water and atmospheric air across the globe that have a major impact on the human and livings health. In worldwide, every country government increasing the importance to improve the outdoor air pollution monitoring and control to provide quality of life and prevent the citizens and livings life from hazard disease. We proposed the environmental dust level detection method for outdoor facilities using sensor fusion technology to measure precise micro-dust level and monitor in realtime. In this proposed approach use the camera sensor and commercial dust level sensor data to predict the micro-dust level with data fusion method. The camera sensor based dust level detection uses the optical flow based machine learning method to detect the dust level and then fused with commercial dust level sensor data to predict the precise micro-dust level of the outdoor facilities and send the dust level informations to the outdoor air pollution monitoring system. The proposed method implemented on raspberry pi based open-source hardware with Internet-of-Things (IoT) framework and evaluated the performance of the system in realtime. The experimental results confirm that the proposed micro-dust level detection is precise and reliable in sensing the air dust and pollution, which helps to indicate the change in the air pollution more precisely than the commercial sensor based method in some extent.

Keywords: *Micro-Dust Detection, Air Pollution Monitoring, Internet of Things (IoT), Air Quality Index (AQI).*

1. Introduction

The modern society pollutant the water, air, and soil with rapid industrial development. The outdoor air pollution impacts the major environmental risk to human and other livings health. The recent research studies have revealed the direct relationship between the quality of life and health with air pollutions and how the air pollution progressively impacts the pulmonary functions, cardiovascular problems, respiratory and asthma, etc.

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[1]. The monitoring and controlling air pollution levels are the primary objectives of every country to their citizen's well-being. The air pollution control reduces the burden of disease from lung cancer, heart disease, asthma and chronic and acute respiratory diseases and also controls the global climate conditions to prevent the natural calamities.

The low-power wireless sensor network (WSN) widely adapted for supervising remote physical environment air and water pollution in realtime [2, 3]. However, the existing air pollution monitoring systems cannot provide highly satisfied air quality index (AQI) resolutions of the air dust level information in real-time and very high costs. So we need a cost effective and high precision environmental dust level prediction system for the outdoor facilities to control the air pollution.

In this paper, we propose the outdoor facility air pollution monitoring system based on state-of-the-art IoT with sensor fusion techniques for micro-dust level detection and remote monitoring. In this proposed sensor data fusion method, we use the dust level detection based on camera sensor and commercial dust level detection sensors to detect the micro-dust level detection. The camera sensor uses the vision based optical flow method with machine learning technique to detect the dust level. The measured dust level data from camera sensor technique is fusion with commercial dust level sensor data to detect precise micro level dust of the outdoor facilities in real-time. The measured dust level transmitted to air pollution monitoring using Long-Term Evolution (LTE) communication technology using IoT protocol for remote monitoring. The proposed outdoor facility micro-dust level detection emulated on raspberry pi based open-source hardware platform and measure the performance of the outdoor facilities air pollution monitoring in realtime.

The air pollution monitoring system conceptual model is discussed in section 2. In the section 3, this paper describes the micro-dust level detection and monitoring of the proposed air pollution monitoring system architecture and concepts. The following section 4 presents the experimental results and analysis of the proposed micro-dust level detection and monitoring. Finally, the conclusions are drawn based on the analysis in the section 5.

2. Air Pollution Monitoring System

The world health organization estimated that the outdoor air pollution cause more than 4.2 million premature deaths worldwide every year in cities and rural areas due to the exposure to the small particulate matter (PM) of 2.5 microns or less in diameter ($PM_{2.5}$) in air which directly cause respiratory disease, cardiovascular and cancers The air pollution monitoring is essential for every county local authority as well as for the industries to maintain air quality in order to preserve human and other livings health due modern industrialization. The cost of air pollution harness may become a heavy burden for individuals and governments if the air quality continues to deteriorate. Thus, the air pollution monitoring systems are very important in effectively monitoring environmental air condition before the environmental situation becomes worse.

In general, the air pollution monitoring system uses the WSN technology which includes basic remote sensing and wireless transmission techniques to monitor the air pollution parameters like particulate matter ($PM_{2.5}$), Ozone (O_3), Nitrogen Dioxide (NO_2), temperature, relative humidity, dew point, etc. The traditional air pollution monitoring system stations are large sizes and very high costs for system installation and maintenance and needed time consuming procedure in offline to measure the precise air pollution level [4]. The recent rapid development of IoT technology helps to design a cost-effective air quality measurement system that can sense and transmit the remote air pollution level and transmitted to the data servers using LTE based wireless communication technology [5-9]. Each sensing unit of the air pollution monitoring system can be freely joined in the network or separated from the network, which is designed in parts to meet various demands. Fortunately, now days, with the most recent and modern technologies, the solutions used for Air

Quality monitoring are becoming not only more precise but also faster at measuring. Recently the sensor based data acquisition devices are becoming smaller with more affordable cost than ever before in market. The architecture of the modern air pollution monitoring system model is shown in Figure 1.

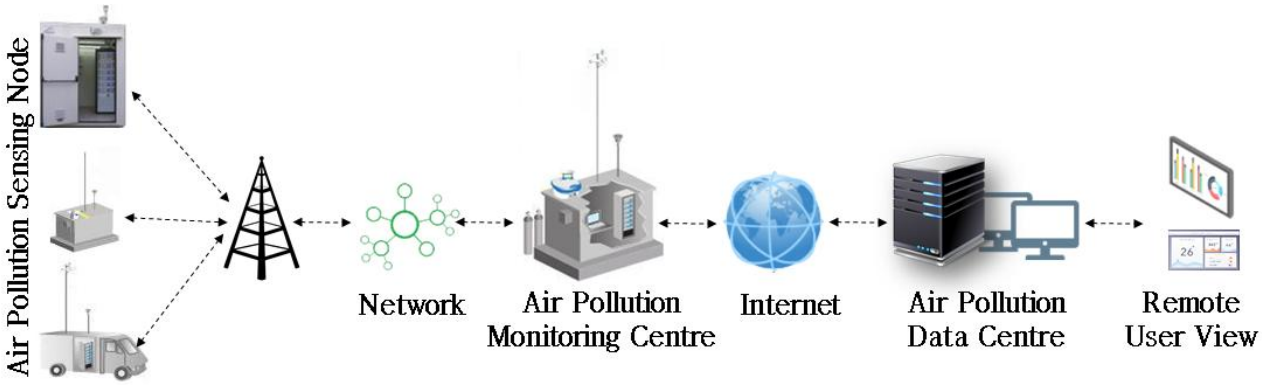

Figure 1. Architecture of air pollution monitoring system

There are various portable and cost effective air quality measurement sensors are developed and used in the air pollution monitoring system. The main pollution sources are the tiny dust particles with less than 2.5 micrometers aerodynamic diameter, i.e., $PM_{2.5}$, which includes the different type poisonous chemicals particles and that can be easily breathed into human lungs. The PM sensor developed without a complicated estimation process to do the reliable air dust level measurement in a second for the outdoor facilities [9, 10]. But the accuracy of these PM sensors also not be as good as traditional air pollution monitoring solution. This paper considered the limitations of air quality measurement sensors and proposes the sensor fusion based method for precise air quality measurement using camera based sensor technology with commercial PM sensor used on the dust level measurement.

3. Micro-Dust Level Detection and Monitoring

The outdoor facility PM in air is considered as the most dangerous air pollutants due to industrial development, transport and household fuels emissions in the world. This influences the global warming and health issues in the earth. There are many researches focusing on precise micro-dust level detection and monitoring in worldwide to control air quality. There are different sensor and monitoring technologies research and development happening worldwide due to rapid development of IoT technologies [11-14]. This paper proposed the IoT based precise environmental micro-dust level detection using sensor fusion technique with LTE connectivity for remote air pollution sensing and monitoring. The proposed sensor fusion based micro-dust level detection module is illustrated in Figure 2.

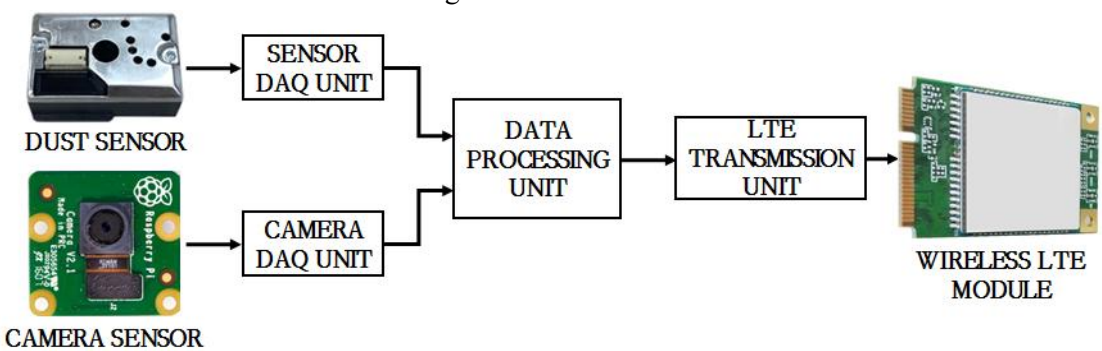

Figure 2. Proposed sensor fusion based micro-dust level detection model

This proposed sensor fusion model uses the camera sensor and $PM_{2.5}$ dust sensor to measure the micro-dust level detection with LTE network connectivity to send the real-time predicted dust level values to the air pollution monitoring centre. The camera sensor designed with Infrared and night vision capability to sense the PM dusts and use the vision optical flow based machine learning technique to measure dust PM level in the air. The dense optical flow method with object detection techniques to measure the dust PM size in the air. The dust sensor detects the $PM_{2.5}$ air quality using light scattering principle. The measured dust level from camera sensor and commercial level sensor data use the kalman filters technique for sensor data fusion to predict the precise micro dust level in air dust pollution.

Figure 3 illustrates the sensor fusion based micro-dust level detection algorithm flow diagram. The estimated micro-dust levels with sensor data fusion technique transmitted to remote system using Message Queuing Telemetry Transport (MQTT) protocol the LTE network infrastructure.

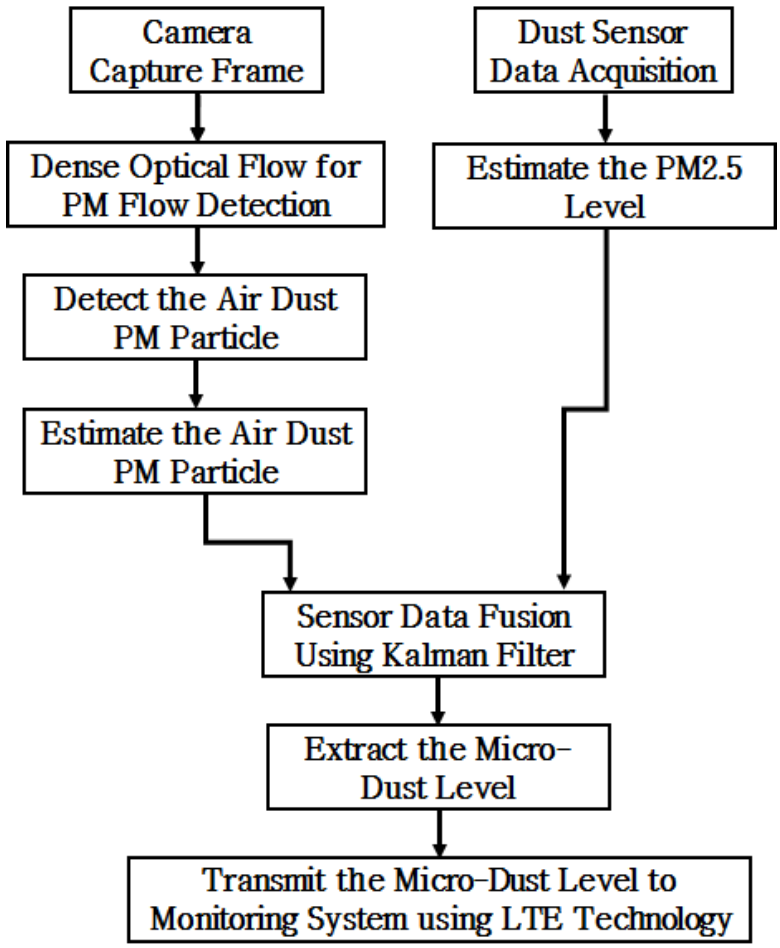

Figure 3. Sensor fusion based micro-dust level detection algorithm flow diagram

4. Experimental Result and Analysis

To evaluate the proposed sensor fusion based micro-dust level detection and monitoring system, we designed the air pollution sensing end node system using Raspberry Pi 3 Model B++ open-source hardware platform with Pi Camera Module v2, MLX90640 thermal camera breakout board, GP2Y1014AU0F dust sensor, and BIT 4G & LTE Hat as shown in the Figure 4. The infrared camera sensor with night vision capability developed using Sony IMX219 8-megapixel image sensor based Pi Camera module and MLX90640

thermal camera breakout for camera sensor technology based air dust level detection. The GP2Y1014AU0F dust sensor used to $PM_{2.5}$ dust level using light scattering principle. The BIT 4G & LTE Hat used to develop IoT connectivity infrastructure with air pollution monitoring centre using MQTT protocol.

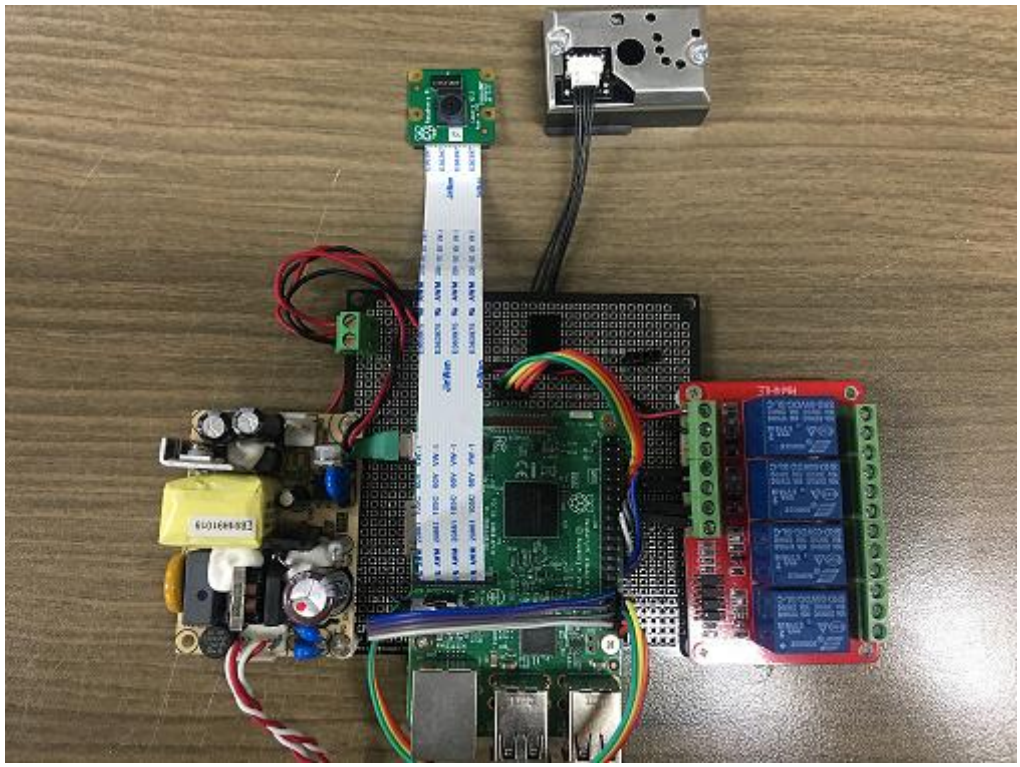

Figure 4. Proposed system prototype model

The camera based dust micro level detection algorithm developed using Raspberry Pi OpenCV framework. The dense optical flow algorithm used to detect the dust level flow and direction and that helps to detect the dust particle object in the outdoor facility air. The custom morphological filtering technique with object detection algorithm developed to detect PM air pollution particles and size of the particles using OpenCV library framework with 2-dimensional (2D) geometrical rule. The GP2Y1014AU0F dust sensor measured $PM_{2.5}$ dust level is fused with camera sensor based PM dust detection level using kalman filter using OpenCV framework to extract precise micro-dust level. The Paho-MQTT library used to transmit the detected micro-dust level to the air pollution monitoring centre using LTE network with IoT BIT 4G & LTE Hat interfaces board.

The proposed sensor fusion technique to detect micro-dust level provides the detection accuracy more than 95% which is corporately very high with commercial dust level sensors with dust level detection accuracy less than 80%. The system performance was compared with GP2Y1014AU0F dust sensor measured $PM_{2.5}$ dust level with sensor fusion techniques and response confirms that the proposed IR camera sensor fusion technique over perform with the traditional approach.

4. Conclusions

This paper presented the sensor fusion technology based environmental micro-dust level detection method for outdoor facilities to measure and monitor precise micro-dust level in realtime. In this paper, we use the

sensor fusion technique with IR camera sensor technology and traditional dust level measurement method for dust level detection to improve the dust-level detection and measurement. The camera sensor based dust level detection approach uses the dense optical flow method to detect the dust flow in outdoor facility pollutant air and the size of the air dust particle is measured using 2D geometrical rule. The traditional dust level measurement sensor data is fused with the camera based micro-dust level data and uses the kalman filter to extract the precise micro-dust level. The observed the dust-level informations are transmitted to monitoring using IoT MQTT protocol through LTE network. The proposed sensor fusion method achieved the 95% micro-dust level detection accuracy compared with traditional dust level detection methods which is provides only around 80% detection accuracy.

Acknowledgement

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