A novel approach for measuring the black level of the ship smoke

Jianbo Hu¹, Shitao Peng¹, Mengtao Deng¹*

¹ Key Laboratory of Environmental Protection Technology on Water Transport, Ministry of Transport, Tianjin research institute for water transport engineering, M.O.T., Tianjin, 300456, China

*Corresponding author’s e-mail: zhda@stud.tjut.edu.cn

Abstract. With the development of the economy, more and more attentions have been paid to the air pollution in China. As a vital means in transportation, the inland-waterway and sea ships possess many incomparable advantages. In the meanwhile, the air pollution caused by ships brought great troubles to the coastal environment. China has begun to strengthen environmental monitoring along the coastline. As a major form of air pollution, the black smoke exhausted by ships bothers the living environment. In this paper, a novel approach is proposed to measure the black level of ship smoke. Moreover, the proposed method is running on the App installed on Android mobile operating platform, which could reach the goal of black level measurement via a precise and convenient manner. Therefore, the proposed approach cloud well facilitates environmental monitoring and protection.

1. Introduction

It was well addressed that the air pollution makes a lot of trouble to our living surroundings, which is being paid much more attentions[1]. Moreover, some laws and regulations have been promulgated in China to detect and restrict the air emissions[2]. As the widespread use of ship in transportation industry, it becomes an inescapable source of the atmospheric pollution. Among several emissions, the black smoke of ship is an important kind of ship emission, which can not affect the coastal landscape, but also bring serious air pollution to atmosphere[3-4]. In ShangHai, a ship black smoke related regulation has been published, which stipulates the ship cannot discharge black smoke. Therefore, an efficient and convenient approach to measure the black level of ship smoke is desperately needed.

Figure 1. The black smoke exhausted by ship.

In this paper, a novel solution is developed to measure the black level of ship smoke. The proposed method is operation in form of App installed on Android mobile operating platform. In this manner,
the extra equipment is completely avoided, which greatly increases the convenience of black level measurement. Moreover, the measurement and calculation of black level is fully automatic. Other than the visual interpretation solutions, the result of which is heavily rely on the surveyor and more subjective. Therefore, the measured result of developed approach is more accurate and objective. The key contributions of our work are as follows:

1) A smoke track algorithm is designed to capture the smoke sub-region of frame.
2) We develop a black level calculate algorithm based on the Ringelman Emittance.
3) An App is developed to aggregate the tracking module and the computing module to reach the goal of black level measurement.

2. Related Works

In this section, the background and the related works about proposed approach will be introduced. When it comes to the black level, the Ringelman emittance is the most adopted metric[5-6]. As shown in Fig 2, the standard Ringelman emittance map is composed of six different images and degrees. In this metric, the black level raises from level 0 to level 5 with the number of black pixels increases, and the brightness or intensity of image decreases.

![Figure 2. The standard Ringelman emittance map. From left to right are Level 0 to Level 5.](image)

Based on the standard Ringelman emittance map, the most sample smoke measurement approach is visual interpretation. However, this manner exists many errors. The other way is by means of the Ringelman emittance measuring instrument[7]. As shown in Fig 3, there are several black masks in lens, which are utilized to assist the measurement. Then the black level of smoke could be determined by contrasting the smoke and black mask. As the visual interpretation, this approach is subjective and may result in great discrepancy.

![Figure 3. The most employed Ringelman emittance measuring instrument.](image)

In this paper, the black level of ship smoke is automatic measured by the developed App, the result of which is much objective and accurate. Moreover, as the App could work on Android mobile operating platform, which cloud be applied to data acquisition and calculation. And the black level of smoke exhausted by ship cloud be retrieved in an end-to-end manner without any other extra equipment. Thus, it’s much more convenient than other solutions. The details of proposed solution will be illustrated in the next section. The remaining parts of this paper is organized as follows: Section 2 describes the related works and common employed instruments. The Section 3 is dedicated...
to the details of proposed approach. Section 4 shows the experiments on different images and videos. Section 5 presents the conclusion of this paper.

3. Proposed Solution

The proposed solution is composed of tracking module and calculating module. The former is assigned to capture the smoke sub-region from the frames of targeted video. And the calculating module is applied to measure the black level of smoke exhausted by ship.

3.1. Tracking Module

As the targeted data of the smoke measurement is video, thus the first step is capturing and tracking the smoke sub-region from the whole video. Moreover, the shape of smoke is changing around all the time, which brings great obstacles to tracking. In this paper, a novel tracking solution is developed to track and capture smoke from the video. As has illustrated, the smoke isn’t rigid body, thus, the tracked object of this module is smoke and part ship body, as shown in Fig 4. The ship body sub-region in tracked object is the rigid body which facilitates the tracking. While the operation, the user will point the quadrant that the smoke exists in the tracked region. Therefore, the smoke sub-region could be well tracked and captured from the original video. There are some frames selected from tracked video.

![Figure 4. Several frames selected from the tracked video.](image)

3.2. Calculating Module

After capturing the smoke sub-region, the next operation is calculating the black level of frame and video, which is based on the Ringelman emittance. And the black level of a video could be confirmed by a set of frames that formed the video. In this model, the black level of selected frame is retrieved via deriving the intensity of Level 0 and Level 5. And the calculation of the intensity of Level 0 and Level 5 are shown in Fig 5 and Fig 6, respectively. The intensity of Level 0 is derived from the smoke sub-region. As there are some pixels which are not contaminated by smoke. Therefore, the brightest part of these pixels should represent the value of Level 0. The intensity of Level 5 is calculated from the whole frame scale[8]. As addressed in, there exist some pixels that the values of which are small, and could be treated as the value of Level 5. Such as, the intensity cloud be retrieved based on the darkest pixels throughout the frame. Moreover, the intensity of Level 0 and Level 5 cloud be retrieved in a self-adapting manner.
Based on the derive Level 0 and Level 5, the black level of a frame can be solved by acquiring the intensity of smoke. The intensity of smoke cloud be calculated via the smoke sub-region. As shown in Fig 7, the darkest pixels in smoke sub-region cloud be adopted as the smoke intensity. And the black level of a frame could be calculated based the pseudo-code in Fig 7. After capturing the black level of a targeted video cloud be treated as the median of the selected frames.

4. Results
In this section, the rendered results of targeted video will be shown. The rendered frames in Fig 8 is employed to demonstrate the calculation of Level 0 and Level 5. The red and purple regions in rendered frames are utilized to indicate the pixels that used to calculate the intensity of Level 0 and Level 5. The rendered results of smoke sub-region in Fig 8 is assigned to illustrate the pixels chosen to calculate the intensity of smoke. As illustrated in Fig 7 and Fig 8, the intensity of Level0, Level 5 and smoke could be precisely derived.
5. Conclusion
In this paper, a novel approach is developed to calculate the black level of smoke exhausted by ship. Other than the most utilized visual interpretation solutions, the proposed approach cloud derive the black level of smoke in an automatic manner. Thus, the result of proposed solution is more objective and precise and there is little to no impact of observers. Moreover, the proposed approach could work on the App in Android mobile operating platform, which doesn’t need any other equipment’s. The proposed approach and App are expected to facilitate the monitor of maritime and environmental protection departments.

Acknowledgments
Special fund for basic scientific research business expenses of central public welfare scientific research institutes (TKS20200307)

References
[1] Giechaskiel B, Maricq M, Ntziachristos L, et.al. Review of motor vehicle particulate emissions sampling and measurement: From smoke and filter mass to particle number[J]. Journal of Aerosol ence, 2014, 67(1):48-86.
[2] Cyrys J, Pitz M, Bischof W, et.al. Relationship between indoor and outdoor levels of fine particle mass, particle number concentrations and black smoke under different ventilation conditions[J]. Journal of Exposure Analysis & Environmental Epidemiology, 2004, 14(4):275-83.
[3] Xiaoxia Wang, Shuang Han, Jianfeng Lu et.al. Controlling and decreasing measures of motor vehicle emissions in China[J]. 2012.
[4] Salo K, Zetterdahl M, Johnson H, et al. Emissions to the Air. Shipping and the Environment. 2016.
[5] Fan-Guo K, De-Wei X U, Jie-Cheng D. Contrast Verification Research on Ringelman Blackness of Electronic Snapshot for Black Smoke Truck[J]. Environmental Monitoring and Forewarning, 2019.
[6] Shelef M. Unanticipated benefits of automotive emission control: reduction in fatalities by motor vehicle exhaust gas. [J]. Science of the Total Environment, 1994, s 146–147:none:93-101.

[7] Discussion on the method of smoke's Ringelman number monitoring[J]. THE ADMINISTRATION AND TECHNIQUE OF ENVIRONMENTAL MONITORING, 1997.

[8] He K, Sun J, Fellow, et al. Single Image Haze Removal Using Dark Channel Prior[J]. IEEE Transactions on Pattern Analysis & Machine Intelligence, 2011, 33(12):2341-2353.