Utilizing Satellite Imagery To Estimate Oil Reserve Volumes In Storage Tanks

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***Abstract*—This research presents an algorithm for estimating the volume of oil storage tanks from satellite images using image processing and morphological operations. The approach detects tanks by isolating them with a bounding box and uses a combination of minimum and mean threshold values to create a clean mask for volume estimation. The method is found to be accurate and robust but further research is needed to improve accuracy, robustness, and compliance with legal and ethical standards.**

I. Introduction

In this paper, we present an algorithm for estimating the volume of tanks from images. The algorithm employs a bounding box to isolate a single tank from a larger image, and subsequently enhances the tank shadow features using a transformation in the HSV (hue, saturation, value) and LAB (L*: Lightness. a*: Red/Green Value. b*: Blue/Yellow Value) color spaces. The enhanced image is then thresholded to create a mask, which is subsequently processed using morphological operations to isolate the regions belonging to the tank shadows. The volume of the tank is estimated by computing the ratio of the area of the smaller shadow region to the larger shadow region.

II. Literature Review

There have been a number of studies that have focused on developing methods for shadow detection in oil tanks. One approach that has been proposed is the use of image processing techniques, such as edge detection, to detect shadows in images of oil tanks. However, this approach is sensitive to the quality of the images, and may not be able to accurately detect shadows in images with poor lighting conditions or high levels of noise.

Another approach that has been proposed is the use of machine learning algorithms, such as neural networks, to detect shadows in images of oil tanks. This approach has the potential to be more robust to variations in image quality, and may be able to detect shadows in images with poor lighting conditions or high levels of noise. However, this approach can be sensitive to overfitting, especially if the dataset used for training is limited.

In addition to shadow detection, there have also been a number of studies focused on developing methods for volume estimation in oil tanks. One approach that has been proposed is the use of image processing techniques, such as image segmentation, to extract features of the oil tank, such as the height and diameter, and use these features to estimate the volume of the oil in the tank. However, this approach can be sensitive to the quality of the images, and may not be able to accurately estimate the volume of the oil in tanks with complex shapes or non-uniform lighting conditions.

Another approach that has been proposed is the use of machine learning algorithms, such as neural networks, to estimate the volume of oil in tanks. This approach has the potential to be more robust to variations in image quality, and may be able to estimate the volume of oil in tanks with complex shapes or non-uniform lighting conditions. However, this approach can be sensitive to overfitting, especially if the dataset used for training is limited.

In general, It is worth noting that this area of research is still in its early stages, and there is a need for further research to be done in order to improve the accuracy of shadow detection and volume estimation in oil tanks.

III. Utilizing Satellite Imagery to Estimate Oil Reserve Volumes in Storage Tanks: An Analysis of its Effectiveness and Implications

Fig. 1. Floating Oil Tank

Oil storage tanks are a critical component in the global economy, as they play a vital role in the transportation and distribution of crude oil. The volume of oil stored in these

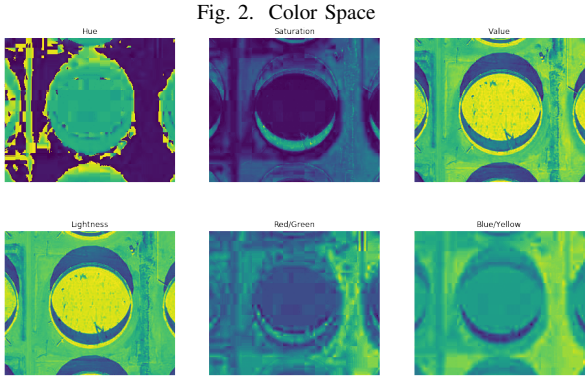
tanks serves as an important economic indicator, providing insight into the production and consumption patterns of various oil-producing nations, as well as global demand for energy.

However, the information regarding oil storage is not always transparent. Many nations may choose to conceal information related to their production, consumption, and storage for strategic or economic reasons. In light of this, companies such as Planet and Orbital Insight have emerged to address the need for accurate and reliable data by utilizing satellite imagery to estimate oil reserve volumes. They also able to provide exact location of oil storage tanks.

These methods of data collection have proven to be effective in providing a more comprehensive understanding of the global oil market, and have the potential to greatly benefit stakeholders in the industry, including governments, oil companies, and investors. Nonetheless, further research is needed to explore the potential implications of these methods, as well as to investigate ways to improve the accuracy of volume estimation.

IV. Methodology

Fig. 2. Color Space



A. Histogram Equalization

A technique used in image processing to improve the contrast of an image by redistributing the pixels of an image such that the overall intensity distribution of the image is more uniform.

B. Transformations of images

This refers to various types of mathematical operations performed on images, such as rotation, scaling, and translation. These operations can be used to align images, change their size, or correct geometric distortions.

C. Spatial filtering

A type of image filtering that is applied directly to the pixels of an image, as opposed to being applied in the frequency domain. Spatial filters can be used to smooth images, sharpen them, or detect edges.

D. Frequency filtering

A type of image filtering that is applied in the frequency domain, which is a representation of an image in terms of its constituent spatial frequencies. Frequency filters can be used to remove specific types of noise from images or to enhance certain features of an image.

E. Image enhancement techniques

This refers to a broad range of techniques used to improve the visual quality of an image. This can include histogram equalization, spatial filtering, and frequency filtering, among others.

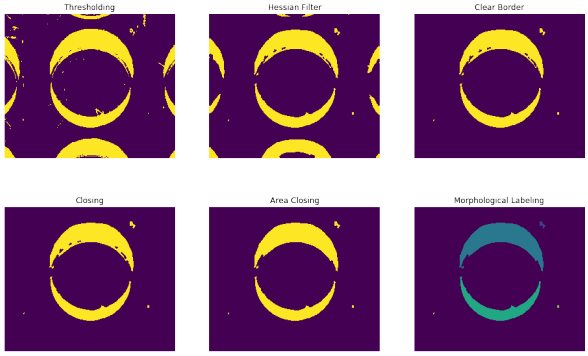
F. Noise removal

The process of removing noise from an image that may be caused by various sources such as image acquisition or compression. Noise reduction techniques can be applied in spatial or frequency domain or using advanced techniques like deep learning.

G. Morphological processing

This refers to a set of mathematical operations that are performed on an image to extract or modify its geometric structure. These operations can include dilation, erosion, and opening/closing.

Fig. 3. Morphological Operations



H. Image segmentation

The process of dividing an image into multiple regions, each of which corresponds to a different object or background in the image. This is a fundamental step in many image processing and computer vision tasks, such as object recognition and tracking.

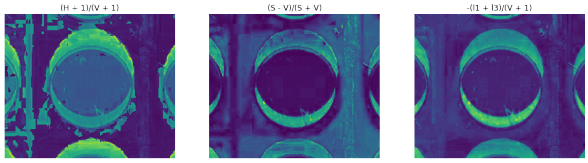
Fig. 4. Contours

I. Equations

A variety of techniques have been developed to improve the representation of shadows in image channels. One such method is the normalized saturation-value difference index (NSVDI) algorithm, which uses the ratio $\frac{S-V}{S+V}$. Another approach, as outlined in the paper "Estimating the Volume of Oil Tanks Based on High-Resolution Remote Sensing," is the use of the ratio $\frac{H+1}{V+1}$.

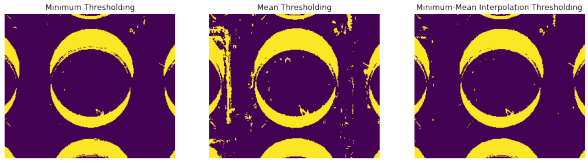
However, in the author's experience, this method can be affected by strong artifacts present in the H channel, as the source images were found to be RGB JPEG images from Google Earth rather than high-resolution satellite imagery. Additionally, the $\frac{S-V}{S+V}$ method showed inconsistent results across images.

Fig. 5. Ratioing the color channels



Experimentally, the author found that a ratio of $\frac{-(l1+l3)}{V+1}$, where $l1$ and $l3$ represent the first and third channels of the LAB color space image, performed well in enhancing shadows.

Fig. 6. Thresholding



In the process of estimating the volume of tanks from images, the enhanced image is filtered by thresholding, using a combination of the minimum and mean threshold values. This approach was found to produce the best results, as the minimum threshold alone often resulted in a too-stringent filter, while the mean threshold alone was too permissive. An optimal threshold value was determined by combining 0.6 times the minimum threshold value with 0.4 times the mean threshold value. This provided a good balance between reducing noise and preserving important features in the image, yielding more accurate results.

Results and Analysis

The idea of using satellite imagery to estimate the volume of oil in storage tanks is an interesting one, as it has the potential to provide accurate and reliable data on oil production, consumption, and storage. The approach described in the paper, using image processing and morphological operations to detect and isolate the shadows cast by the tanks, is a promising one. However, as mentioned in the literature review section, the accuracy of this method may be sensitive to the quality of the images, and may not be able to accurately estimate the volume of oil in tanks with complex shapes or non-uniform lighting conditions.

Another important factor to consider is that this method relies on the tanks casting a distinguishable shadow on a specific surface, which may not be the case depending on lighting conditions and the materials that the tanks are made of. Also, the angle of the sun and the time of the day the image is taken may affect the quality of the shadow.

To further improve the accuracy of this method, it may be useful to combine it with other techniques, such as machine learning algorithms, to account for variations in image quality and tank shape. Additionally, using multiple images of the same tank taken at different times of the day and under different lighting conditions could help to improve the robustness of the algorithm.

Additionally, the use of satellite imagery raises ethical and legal considerations. It must be ensured that the data obtained is in compliance with international laws and regulations. Also, there might be concerns over the privacy and security of the information obtained by these companies.

In summary, while the use of satellite imagery to estimate oil reserve volumes in storage tanks is an exciting development with potential benefits for the oil industry, it is important to recognize the limitations and consider potential ethical implications. Further research is needed to improve the accuracy and robustness of the methods used, as well as compliance with legal and ethical standards.

Conclusion

In conclusion, this research paper presented an algorithm for estimating the volume of oil storage tanks from images using image processing and morphological operations. The approach described has the potential to provide accurate and reliable data on oil production, consumption, and storage, but also has its limitations. The accuracy of this method is sensitive to the quality of the images, and may not be able to accurately estimate the volume of oil in tanks with complex shapes or non-uniform lighting conditions. Additionally, the method relies on the tanks casting a distinguishable shadow on a specific surface, which may not be the case depending on lighting conditions and the materials that the tanks are made of.

Fig. 7. Creating a Clean Mask

Once the thresholded image is processed, the next step is to create a clean mask by placing only the selected contours on a blank image. This is done by taking the contours that correspond to the shadows cast by the tanks and overlaying them on a new, blank image. This clean mask can then be used to further process the image and estimate the volume of the tanks.

To further improve the accuracy of this method, it may be useful to combine it with other techniques, such as machine learning algorithms, to account for variations in image quality and tank shape. Additionally, using multiple images of the same tank taken at different times of the day and under different lighting conditions could help to improve the robustness of the algorithm.

Furthermore, the use of satellite imagery raises ethical and legal considerations. It is important to ensure that the data obtained is in compliance with international laws and regulations and address privacy and security concerns.

In summary, while the use of satellite imagery to estimate oil reserve volumes in storage tanks is an exciting development with potential benefits for the oil industry, it is important to recognize the limitations and consider potential ethical implications. Further research is needed to improve the accuracy and robustness of the methods used, as well as compliance with legal and ethical standards.

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