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Cloud Amount Measurement By Using Machine Learning Technology

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Abstract. In this review paper, the significance of cloud amount measurements in meteorology and the objectives of cloud amount measurement projects have been discussed by reviewing different research papers and articles. Cloud amount measurement is crucial in understanding weather patterns and predicting future weather events, and it can also be used to assess the impact of clouds on climate and support renewable energy production, aviation, and transportation. The paper includes a literature survey of the research papers related to cloud cover detection and estimation using various methods such as digital cameras and algorithms based on longwave downward radiation measurements. Overall, cloud amount measurement projects aim to collect and analyse data on cloud cover and other meteorological parameters to improve weather forecasting, support climate research, and enhance various industries and sectors that rely on accurate weather information.

Keywords: cloud image, image processing, python, cloud amount, oktas

1. Introduction

Cloud amount measurement is an important parameter that meteorological departments use to understand the state of the atmosphere and make weather predictions. Clouds can affect weather patterns, temperature, and precipitation, making them a crucial factor in meteorology. Cloud amount refers to the portion of the sky that is covered by clouds at a given time. It is typically expressed as a percentage or in oktas, which represent eighths of the sky covered by clouds. For example, if half of the sky is covered by clouds, the cloud amount would be 4 oktas or 50%. Meteorological departments use various instruments to measure cloud amount, including ceilometers, sky cameras, and human observations. By tracking changes in cloud amount over time, meteorologists can analyse how the atmosphere is changing and use this information to make weather forecasts. Cloud amount measurements are particularly important in determining the likelihood of precipitation. For example, a high cloud amount could indicate that rain or snow is likely to occur in the near future, while a low cloud amount could suggest that the weather will be sunny and dry. Overall, cloud amount measurements are an important tool for meteorological departments to understand and predict weather patterns, helping them to issue accurate weather forecasts and warnings.

2. Purpose and objectives:

The objectives of a cloud amount measurement project may vary depending on the specific context and goals of the project. However, some potential objectives of such a project could include:

1. Monitoring weather patterns: One of the primary objectives of a cloud amount measurement project may be to monitor and track changes in weather patterns over time. By collecting data on cloud amount and other meteorological parameters, the project team can gain insights into how weather patterns are evolving and make predictions about future weather events.
2. Improving weather forecasting: Cloud amount measurements can be used to improve weather forecasting accuracy. By analysing changes in cloud cover and using this information in combination with other meteorological data, forecasters can create more accurate and reliable weather predictions.
3. Assessing the impact of clouds on climate: Clouds play an important role in regulating the Earth's climate, and understanding how cloud cover is changing over time is critical to understanding climate change. A cloud amount measurement project may aim to collect data on cloud cover to help assess the impact of clouds on the Earth's climate.
4. Supporting renewable energy production: Cloud cover can have a significant impact on renewable energy production, particularly for solar energy. By monitoring cloud amount and other meteorological parameters, a cloud amount measurement project can help renewable energy producers optimize their operations and plan for changes in weather conditions.
5. Supporting aviation and transportation: Cloud cover can impact aviation and transportation by affecting visibility and causing delays or cancellations. A cloud amount measurement project may aim to collect data on cloud cover to help aviation and transportation professionals plan for potential disruptions and improve safety.

Overall, the objectives of a cloud amount measurement project are to collect and analyse data on cloud cover and other meteorological parameters to improve weather forecasting, support climate research, and enhance various industries and sectors that rely on accurate weather information.

3. Literature survey:

a. Cloud cover by a Ground-Based Digital Camera

This paper describes a simple method of field estimating the sky cloud coverage percentage at the Brazilian Antarctic Station using a digital colour camera and a new algorithm that classifies each pixel based on a decision process. The accuracy of the method was tested against clear-sky and overcast-sky conditions and achieved rates of over 94% and 99%, respectively. A comparison test was also performed with two human observers, and the correlation coefficients between human observers and the automatic method were reported. Overall, the paper suggests that the proposed method is effective in estimating sky cloud coverage percentage with high accuracy. [1]

b. Automatic cloud amount detection by surface longwave downward radiation measurements

The paper discusses the challenges of automating cloud cover detection and introduces an algorithm called APCADA (automatic partial cloud amount detection algorithm) that can detect partial cloud amounts based on measurements of longwave downward radiation, temperature, and relative humidity. This algorithm provides cloud cover estimates every 10 minutes and is applicable to radiation stations without knowledge of synoptic cloud observations. The article compares naked-eye observations from seven radiation sites to APCADA estimates and finds that they agree within a certain range of cloud amount difference. This paper also discusses other cloud detection methods such as ceilometers, IR pyrometers, and sky imagers, which have various disadvantages.[2]

c. Cloud Cover by a Ground-Based Digital Camera.

This paper describes a method for field estimating the percentage of sky cloud coverage for various applications at the Brazilian Antarctic Station, Ferraz. The method uses a digital colour camera to acquire images in the visible spectrum and a new algorithm to classify each pixel based on a decision process using information from the saturation component of the intensity, hue, and saturation space (IHS). The images were acquired with a limited field of view of 36° pointing to the camera's zenith to prevent direct sunlight from reaching the camera's internal charge-coupled device (CCD). The accuracy of the method was tested against clear-sky and overcast-sky conditions, and the results showed that the method was accurate, with accuracy rates over 94% and 99%, respectively. A comparison test was also performed with two human observers, and the correlation coefficients between human observers and the automatic method were reported. Overall, the abstract suggests that the proposed method is effective in estimating sky cloud coverage percentage for various applications at the Brazilian Antarctic Station.[3]

d. **Algorithm by deep learning to detect cloud amount**

The paper discusses the challenges of reliable cloud detection in optical satellite-based remote sensing. Existing methods for cloud detection based on spectral signatures of individual pixels do not incorporate spatial patterns, leading to misclassification of highly reflective surfaces like human-made structures or snow/ice. The paper proposes a deep learning model called RS-Net based on the U-net architecture for cloud detection in optical satellite imagery. The model is trained and evaluated using the Landsat 8 Biome and SPARCS datasets, and it shows state-of-the-art performance, especially over biomes with hardly distinguishable scenery like clouds over snowy and icy regions. The paragraph also discusses how training the RS-Net models on data from an existing cloud masking method leads to increased performance compared to the original method. The RS-Net model has a fast classification time of 18.0 ± 2.4 s for a full Landsat 8 product, making it suitable for production environments.[4]

e. **Weather forecasting (cloud cover)**

The paper discusses a study comparing the vertical distributions of fractional cloud coverage obtained from different sources over the eastern United States. The study analyzes data from the U.S. Air Force 3DNEPH satellite, aircraft, and surface-based analysis, as well as standard meteorological observations, interpolated onto the same three-dimensional grid. The analysis finds that cloud cover is highest near 900 mb, with a maximum of 35% cloud cover, and decreases to near-zero at the surface. The study also identifies correlations between cloud cover and various meteorological factors, such as relative humidity, vertical velocity, wind shear, and temperature lapse rate. The analysis suggests that estimating cloud cover and other meteorological factors averaged over large areas, especially in the upper troposphere, is subject to considerable uncertainty. The study also suggests that resolution-dependent algorithms can be used to estimate cloud coverage from relative humidity. Finally, the study notes that many meteorological, climate, and chemical models of the atmosphere underestimate cloud amounts when relative humidities are less than 90%–95% during the analysis period.[5]

f. **CATEGORIZATION OF CLOUD IMAGE PATCHES USING AN IMPROVED TEXTON-BASED APPROACH**

Cloud analysis and classification is important for various applications, but manual classification by experts is expensive and infrequent. Automatic cloud classification methods are necessary, and the World Meteorological Organization recommends a genera-based classification. The proposed method integrates both colour and texture information to classify sky/cloud patches, adapting Varma and Zisserman's textons. The method achieves very good classification accuracy according to extensive experiments on a large-scale database.

The analysis and classification of clouds are crucial for numerous applications such as weather forecasting, climate modeling, satellite communication, and solar energy production. However, manual classification is expensive and infrequent. Therefore, there is a need for automatic and efficient cloud classification methods. The World Meteorological Organization (WMO) recommends a genera-based classification, which is based on the shape, structure, transparency, arrangement, texture, color, and height of clouds. The proposed approach integrates color and texture information to classify sky/cloud patches, and achieves good classification accuracy according to extensive experiments on a large-scale database. The approach adapts Varma and Zisserman's textons, and eliminates several pre-processing stages and fixed thresholds that are used in other approaches. Overall, the proposed method is a promising technique for cloud categorization tasks.[6]

g. **A CAPTCHA that Exploits Interest-Aligned Manual Image Categorization**

The growing use of CAPTCHAs (Completely Automated Public Turing test to tell Computers and Humans Apart) or HIP (Human Interaction Proof) has become increasingly popular to prevent the exploitation of public web services by bots and automated scripts. CAPTCHAs are a test requiring users to solve a challenge before accessing the service. There are two types of CAPTCHAs, Class I and Class II, which rely on the secret information of a random number and a secret high-entropy database, respectively. The latter type is more difficult to build since it requires a sufficient number of classified, high-entropy entries in the database. CAPTCHAs can generate unique challenges with concise software code and have no long-term secrets to guard. However, current CAPTCHAs with distorted texts are less effective in differentiating humans from machines. The development of Class II CAPTCHAs, which require recognizing features of photographic images captured from the physical world, has led to a broader gap between human and non-human success rates. One significant issue in building a Class II CAPTCHA is populating the secret database with classified high-entropy entries. Existing approaches for doing this involve mining a public database or providing entertainment as an incentive for manual image categorization. Despite the challenges in building CAPTCHAs, they remain an essential tool for preventing automated exploitation of public web services.[7]

h. **Cloud base height measurement system based on stereo vision with automatic calibration**

This paper discusses the significance of clouds in various fields such as weather prediction, climate studies, and aviation safety, and highlights the crucial parameters including cloud height, type, and cover percentage. The paper further presents recent improvements in the development of a low-cost cloud height measurement setup based on stereo vision with consumer digital cameras, which are calibrated using the position of stars in the night sky. An experimental uncertainty analysis of the calibration parameters is also performed. The study provides cloud height measurement results, which are then compared with LIDAR measurements. The low-cost cloud height measurement setup has the potential to provide an alternative solution for cloud height measurements, making it an attractive option for those who do not have access to expensive LIDAR equipment. The results of the study could be useful for enhancing weather prediction, climate studies, and aviation safety, and contribute to the development of cost-effective cloud height measurement systems.[9]

i. **A Trade-off Analysis of a Cloud-Based Robot Navigation Assistant Using Stereo Image Processing**

This paper discusses the use of cloud computing for computation offloading in the field of robotics, specifically for a vision-based navigation assistance task in a service mobile robot. The paper presents a prototype based on a ROS-based mobile robot with on-board stereo cameras. The extracted information is processed by a private cloud platform consisting of five bare-metal nodes with AMD Phenom 965 × 4 CPU, using the cloud middleware Openstack Havana. The actual task is the shared control of the robot teleoperation, which involves filtering the teleoperated commands with the detected obstacles to prevent collisions. The paper explores various offloading models for this case and analyzes their performance using different communication technologies. The paper also presents real navigation results in a domestic circuit, which demonstrate that offloading computation to the cloud improves performance and navigation results compared to the case where all processing is done by the robot. Overall, the paper demonstrates the viability of cloud offloading in low-level and intensive computing tasks in robotics, with potential applications in various fields.[9]

j. **Error Characteristics of Ceilometer-Based Observations of Cloud Amount**

This paper discusses the limitations of cloud cover measurements obtained from ceilometer observations, which form an important component of automated weather observation networks. The accuracy of ceilometer-based cloud amount measurements is impacted by the limited vertical range and areal extent of its observations. To analyze the magnitude of errors associated with ceilometer-based observations of cloud amount, a multiyear collocated dataset of observations from a laser ceilometer, a total sky imager (TSI), and a micropulse lidar (MPL) is used. The study simulates the observations of operational ceilometers and highlights that the limited areal coverage of ceilometers results in errors when skies are heterogeneous, but these errors are small compared to those caused by the limited vertical range. The presence of upper-level clouds makes observations of clear sky or few clouds erroneous. These errors are diurnally and seasonally dependent, with the greatest error observed in the morning and summer, respectively. Overall, the study demonstrates that ceilometer-based observations of overcast skies are the most accurate, with a root-mean-square error of cloud fraction in overcast conditions an order of magnitude lower than for the dataset as a whole, owing to the spatial homogeneity and low base of stratus clouds. The study highlights the need for accurate cloud cover measurements and the potential limitations of ceilometer observations.[10]

4. Conclusion:

Cloud amount measurement is an important tool for meteorological departments to understand and predict weather patterns, helping them to issue accurate weather forecasts and warnings. Cloud amount refers to the portion of the sky that is covered by clouds at a given time and is typically expressed as a percentage or in oktas.

Meteorological departments use various instruments to measure cloud amount, including ceilometers, sky cameras, and human observations. The objectives of a cloud amount measurement project may vary depending on the specific context and goals of the project, but may include monitoring weather patterns, improving weather forecasting accuracy, assessing the impact of clouds on climate, supporting renewable energy production, and supporting aviation and transportation.

This literature survey presented ten papers that describe methods for cloud cover detection and estimation using different instruments and algorithms, highlighting the challenges and advantages of each method. Overall, cloud amount measurement is a critical aspect of meteorology and has many important applications in various fields, including climate research, renewable energy production, and transportation safety.

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