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Harish Sharma
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Communication and Intelligent Systems

Proceedings of ICCIS 2021

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Volume 461

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Proceedings of ICCIS 2021

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ISSN 2367-3370 ISSN 2367-3389 (electronic)
Lecture Notes in Networks and Systems
ISBN 978-981-19-2129-2 ISBN 978-981-19-2130-8 (eBook)
https://doi.org/10.1007/978-981-19-2130-8

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

This book contains outstanding research papers as the proceedings of the 3rd International Conference on Communication and Intelligent Systems (ICCIS 2021), which was held on 18–19 December 2021 at National Institute of Technology Delhi, India, under the technical sponsorship of the Soft Computing Research Society, India. The conference is conceived as a platform for disseminating and exchanging ideas, concepts, and results of researchers from academia and industry to develop a comprehensive understanding of the challenges of the advancements of intelligence in computational viewpoints. This book will help in strengthening congenial networking between academia and industry. This book presents novel contributions in areas of communication and intelligent systems, and it serves as reference material for advanced research. The topics covered are intelligent system: algorithms and applications, intelligent data analytics and computing, informatics and applications, and communication and control systems.

ICCIS 2021 received a significant number of technical contributed articles from distinguished participants from home and abroad. ICCIS 2021 received 476 research submissions from 43 different countries, viz. Australia, Bahrain, Bangladesh, Brazil, Bulgaria, Burkina Faso, Chile, China, Ecuador, Egypt, Ethiopia, Finland, Germany, India, Iran, Iraq, Italy, Japan, Liberia, Malaysia, Mauritius, Morocco, Nepal, Oman, Poland, Portugal, Romania, Russia, Saudi Arabia, Serbia, Singapore, Slovakia, South Africa, South Korea, Sri Lanka, Thailand, Turkey, Ukraine, United Arab Emirates, UK, USA, Viet Nam, and Yemen. After a very stringent peer-reviewing process, only 92 high-quality papers were finally accepted for presentation and final proceedings.

This book presents novel contributions in areas of communication and intelligent systems, and it serves as reference material for advanced research.

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Detecting Equatorial Plasma Bubbles on All-Sky Imager Images Using Convolutional Neural Network

Worachai Srisamoodkham, Kazuo Shiokawa, Yuichi Otsuka, Kutubuddin Ansari, and Punyawi Jamjareegulgarn

Abstract This paper proposes initially to apply convolutional neural network (CNN) for detecting the equatorial plasma bubbles on the ASI images. The considered CNN model is the YOLO v3 tiny model under a deep learning API (Keras), running on top of the machine learning platform (TensorFlow). Our program for EPB detection is written in Python that is extended easily to combine into a space weather web site for detecting and notifying EPBs in our next step. The results show that the YOLO v3-based CNN can detect the EPBs in ASI images with different intensities obtained from many countries. The threshold is tested and selected to be 0.40 suitably for detecting the anomaly (EPB existence). The maximum anomalous value is selected to decide the EPB occurrence.

Keywords ASI · Convolution neural network · Plasma bubble · YOLO

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1 Introduction

Plasma instabilities over equatorial ionosphere can be a major source of large- and small-scale density depletions during after sunset and after midnight. The depleted plasma over magnetic equator (so-called equatorial plasma bubble or EPB) formulates at the bottomside F region and rises upwardly with its structure elongating along the magnetic field lines. The plasma instabilities exist various scales ranging from 10 cm to 1000 km where they can disrupt HF communication, satellite communication, positioning, as well as navigation systems within $\pm 20°$ latitudes around geomagnetic equator [1]. In general, these perturbed ionosphere conditions can lead to another phenomenon named as equatorial spread-F (ESF) in F region, because they affect directly the HF communications by producing the echo spreads in ionograms. Both EPB and ESF have been known as the main sources for Global Navigation Satellite System (GNSS) disturbances. The scintillation is the amplitude and phase fluctuations of signals that leads to disrupt satellite-based communications and deteriorate the GNSS positioning accuracy [2, 3]. The main reason is that the sudden density depletions inside EPBs disturb the GNSS velocities passing the ionosphere. This is why the occurrence characteristics as well as probabilities of EPB have been studied for space weather and ionospheric physics. (e.g., [4, 5]).

Basically, the F region plasma irregularities at height 250–350 km can be observed as dark EPBs and bright plasma blobs. The plasma blobs were observed firstly by OI 630.0 nm all-sky imagers (ASIs) at Brazil [4]. Nade et al. [5] investigated the simultaneous plasma blobs and EPBs over low latitudes, but the generation mechanism of EPBs and blobs is not obviously comprehended [6] and should be made additional investigation. Paznukhov et al. [7] studied firstly the EPBs and the scintillations over Africa in 2010 for monitoring the ionospheric irregularities. Their results released that the EPBs are directly related to the scintillations and the scintillation severity relies on EPB depth. The scintillation amplitude is identified by S4 index, and the EPBs are analyzed based on spectral analysis and GPS TEC observation. Shiokawa et al. [8] conducted the experiments of atmospheric and ionospheric waves in the upper atmosphere over several countries using ASIs. Their results reported about the features of small gravity waves and medium disturbances in mesosphere, thermosphere and ionosphere. As for our earlier EPB investigations, the obvious airglow depletions incurred by EPBs can be observed by several OMTIs and analyzed at Chiang Mai, Darwin, and Kototabang etc. After storing the ASI images, they will be post-processed and analyzed with some kinds of program such as MATLAB, SCILAB, etc.

Likewise, numerous literatures have proposed several methods to analyze the all-sky image data. For example, Kubota et al. [9] introduced a method to convert the pixel ASI images into the actual coordinates at the airglow emission layer. Afterward, Narayanan et al. [10] present an approach to convert the pixel values into the respective latitude–longitude values of each ASI image. In Thailand, the ASIs of optical mesosphere thermosphere imager were also installed at Chiang Mai and Chumphon provinces to monitor plasma bubbles. The ASI images of these two regions are very important so as to investigate the EPB generation mechanism, the EPB movement and the impact of EPB on HF communication, positioning, and navigation over equatorial and low latitudes [11]. However, the EPB detection and notification have not proposed simultaneously; therefore, the authors have an idea to detect the nighttime ASI images and classify each ASI image with or without EPBs on web applications using convolution neural network (CNN). The ASI images at Chiangmai, Thailand, is employed as the train dataset for the proposed CNN method. Meanwhile, the ASI images are also taken from previous published manuscripts to be the test dataset such as Lynn et al. [15], observed at Darwin, Australia; Takahashi et al. [16], observed at São Luis, Brazil; and Makela et al. [17], observed at Haleakala, Hawaii [17].

2 Optical Mesosphere Thermosphere Imagers (OMTI)

Optical Mesosphere Thermosphere Imagers (OMTI) was constructed by ISEE of Nagoya University in 1997 in order to investigate the dynamics of airglow emissions in upper atmosphere. The OMTI consists of all-sky imagers (ASIs), photometers, and interferometer. The imagers employ some cooled CCDs of 512 × 512 pixels. All of the ASIs in the OMTI have at least four filters and some gases' filters. The BPF bandwidths are about 1–2 nm and the ASI sensitivities are less than 0.4 counts per second providing smaller than 4000 count/R/s. Further details of the OMTI can be read and studied in Shiokawa et al. [8], and the airglow images of OMTI are obtained from the web: https://stdb2.isee.nagoya-u.ac.jp/omti/index.html. Otsuka et al. [9] suggested that the ASIs of OMTI are a crucial instrument for better understanding the coupling between ionosphere and thermosphere and detecting the EPBs. Figure 1 shows the examples of airglow images detected by OMTI at Chiang Mai, Thailand, on February 2, 2020.

3 YOLO Tool

Object detection is a significant mission that is concerned to identify the existence and the localization of one or more objects in a given figure. The methods of object recognition and classification seem to be the challenging tasks. Hence, the YOLO with convolutional neural networks (CNNs) approach has been proposed to be the modern tool for performing the real-time object detection [12]. That is the reason why the YOLO is selected to detect the real-time EPBs from ASI images in this work.

YOLO tool was built and released to the public in April, 2018. It is recognized to outperform the previous YOLO versions. Its algorithm depends on a variant of Darknet which has 53 hidden-layer network trained on Imagenet. The latest version of YOLO is YOLOv3. In this work, a CNN program is coded with python using YOLOv3 model that is contained in Keras API and TensorFlow. Note that TensorFlow

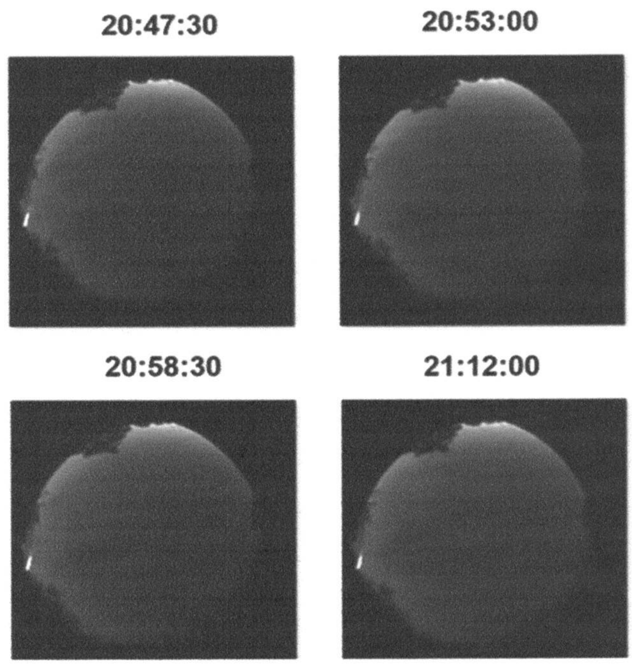


Fig. 1 The airglow images detected by all-sky airglow imagers of OMTI at Chiang Mai, Thailand, on February 2, 2020

is the open-source of Google for developing the applications based on machine learning and deep learning. It can be used on several platforms (e.g., windows, Linux, etc.) for making machine learning.

As for YOLO v3, a fully convolutional neural network (CNN) with larger than 100 layers can be processed for its object detection due to 53-hidden layers. The operating procedure of YOLO v3 is depicted in Fig. 2 where YOLO v3 includes the down-sampling three levels for the input image dimensions. Especially, the object prediction of YOLO v3 are forecasted using logistic regression [13]. As for several advantages of YOLO v3, it is thus employed to train the all-sky imager (ASI) images and classify those images with or without plasma bubbles in this work.

4 Results

The ASI images with and without EPBs at Chiang Mai, Thailand, were used as the training images. Afterward, those images were extracted the image features and classified with and without EPBs using YOLOv3 (CNN model). YOLOv3 tiny model

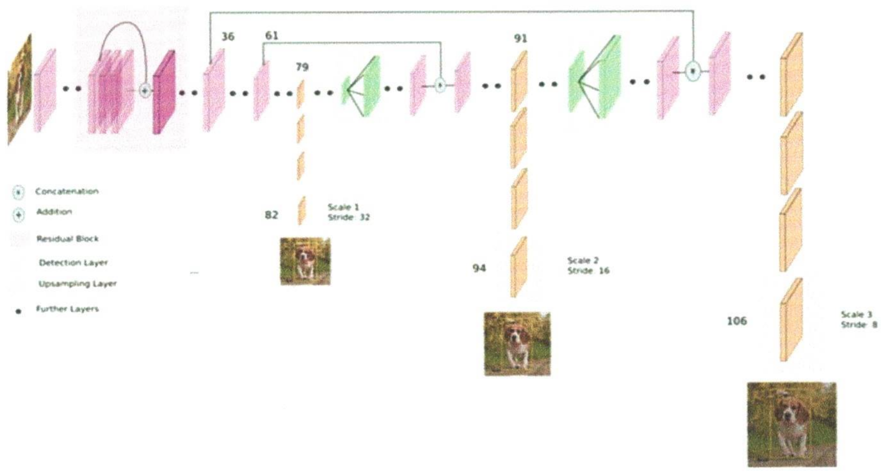


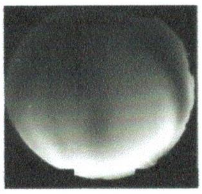
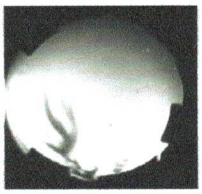
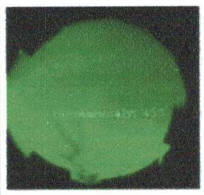
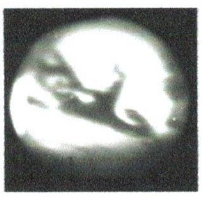
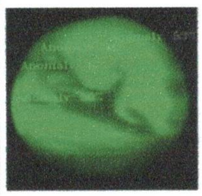
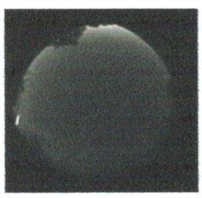
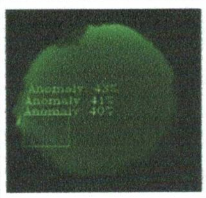
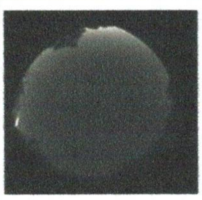
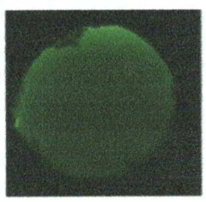
Fig. 2 The operating procedure of YOLO v3 [13]

was employed in this work, because it has a slightly lower recognition accuracy, but runs faster as compared to the standard model. The accuracy and the computational power of the tiny model are equal to 33.1 and 5.56 Bn, respectively, that are much less than those of the standard model [14]. During training the number of ASI images, we find that the suitable threshold is equal to 0.40 (or 40%) for classifying the EPBs and also use the word "anomaly" in each image to represent the EPB occurrence. In Table 1 case (a)–(d), the ASI images with EPBs show their anomalies of greater than and equal to 40%. The maximum anomalies in each ASI image are selected to decide surely the EPB existence. In contrast, the case e) of Table 1 depicts an ASI image without EPBs whose anomaly is less than 40% (no anomaly).

5 Conclusion

Equatorial plasma bubble (EPB) in all-sky imager (ASI) images are detected using the convolutional neural network (CNN) for the first time. The YOLO v3 "Tiny" model is used to detect the EPBs due to its several benefits. Our EPB detection program is written in Python that can be gathered into a web site at once. After gathering the ASI images from different countries and Chiang Mai, Thailand, we start extracting the features and classify the ASI images with and without EPBs like "supervised learning" with YOLO v3-based CNN. Note that the YOLO v3 framework is based on Keras API (deep learning) operated on TensorFlow (machine learning) platform. We find that the CNN model can be used to detect admirably the EPBs in ASI images with the suitable threshold setting of 0.40. This threshold was defined after more than two hundred ASI images with and without EPBs were trained and

Table 1 ASI Images before and after CNN model with maximum anomalies and sources

Case	ASI Images Before CNN model	ASI Images After CNN model	Maximum of anomalies	Image Sources
(a)			54%	Lynn et al. [15], observed at Darwin, Australia
(b)			45%	Takahashi et al. [16], observed at São Luis, Brazil
(c)			53%	Makela et al. [17], observed at Haleakala, Hawaii
(d)			43%	Chiang Mai, Thailand, observed by Nagoya University
(e)			No anomaly	Chiang Mai, Thailand, observed by Nagoya University

classified completely. In the future, this CNN-based EPB detection program will be combined on the space weather web site and will be used as an EPB precursor over Thailand.

Acknowledgements This research is funded by BTFP organization (project code: B2-001/6-2-63). The authors would like to express the gratitude to the ASI images taken from [15–17]. Particularly, several ASI images employed to train the CNN model were obtained from Chiang Mai station owned by Nagoya University, Japan.

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