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Sunspot drawings handwritten character recognition method based on deep learning

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HIGHLIGHTS

- Convolution neural network (CNN) is applied to recognize handwritten characters in scanned sunspot drawings.
- A recognition model for handwritten characters is obtained by CNN method.
- The daily full-disc sunspot numbers and full-disc sunspot areas can be obtained from the recognized information.

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ABSTRACT

High accuracy scanned sunspot drawings handwritten characters recognition is an issue of critical importance to analyze sunspots movement and store them in the database. This paper presents a robust deep learning method for scanned sunspot drawings handwritten characters recognition. The convolution neural network (CNN) is one algorithm of deep learning which is truly successful in training of multi-layer network structure. CNN is used to train recognition model of handwritten character images which are extracted from the original sunspot drawings. We demonstrate the advantages of the proposed method on sunspot drawings provided by Chinese Academy Yunnan Observatory and obtain the daily full-disc sunspot numbers and sunspot areas from the sunspot drawings. The experimental results show that the proposed method achieves a high recognition accurate rate.

1. Introduction

Historical sunspot drawings have been widely used to study the solar activity during the past centuries, dating back in the past to excavate the series of sunspots numbers (Lefevre and Clette, 2014). It is mostly because the close connection between the solar movement and the terrestrial climate that makes the studies of the solar movement based on the analysis of early sunspot observation important (Cristo et al., 2011). In recent years, a great effort has been made to make software tools to analyze sunspot drawings (Cakmak, 2014; Arlt, 2011; Hrzina et al., 2007). Accurate and almost continuous record of the sunspots are determined from digitized sunspot drawings(Arlt, 2009; 2011; Arlt and Frohlich, 2012). Reliable sunspot catalogues in historical times including the 17th century, obtained from sunspot drawings, can be provided to the scientific community (Carrasco et al., 2014; Casas and Vaquero, 2014; Vaquero et al., 2015). Lefevre and Clette merge the information from parallel catalogs to form a better central database that collects a much more comprehensive record of sunspots and sunspot groups (Lefevre and Clette, 2014). Sunspot drawings can be also used to measure the position of sunspots and estimate the solar rotation rate by analyzing the changes in the position of the sunspots with time (Arlt and Frohlich, 2012). The contemporary sunspot drawings have made great contributions to obtain the information on surface rotation during these centuries (Sánchez-Bajo et al., 2010; Clette et al., 2014), present new methods to correct the International Sunspot Number and the Group Number, and then consider the implications on our knowledge of solar activity over the last 400 years. On the other aspect, sunspot drawings are the original material for us to have a deep study of the long-term evolution of the solar cycle (Clette, 2011). In addition, because of the intimate connection between the activity and the solar dynamo, studies of solar rotation based on historical sunspots drawings appears increasingly important (Tobias, 2009).

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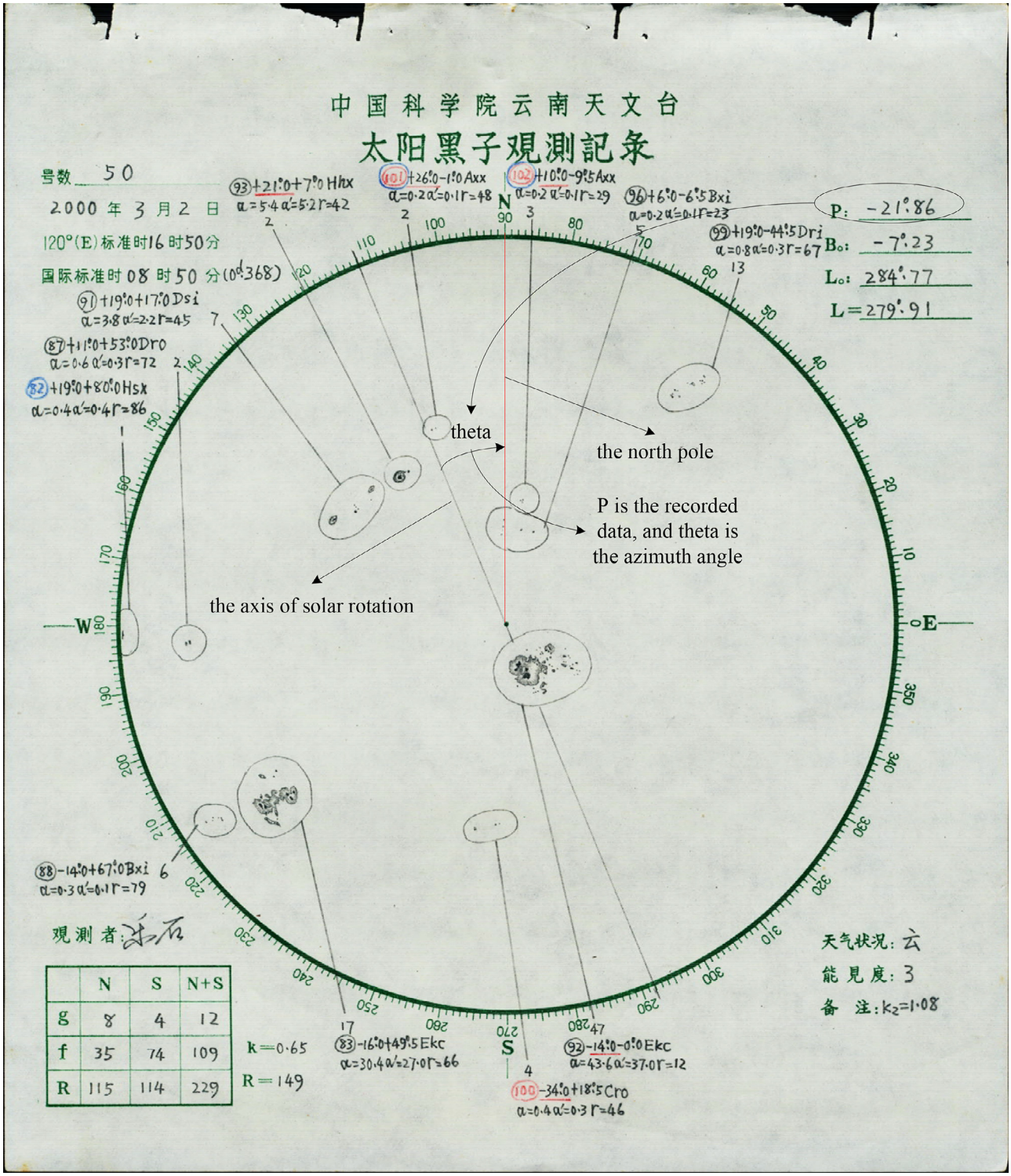

Fig. 1. One example of sunspot drawings preserved by Yunnan Observatory.

Science the late 1930s,Chinese observatories have begun observing sunspot activity and the sunspot drawings achieved by Yunnan Observatory have accumulated over more than 20,000. It is an integral part of Chinese sunspot observations. One example of sunspot drawings preserved by Yunnan Observatory is shown in Fig. 1. According to these sunspot drawings, the observation date, Beijing time, UTC, Wolf Number, sunspot group number in the South and North, azimuth angle between the axis of solar rotation and the north pole, latitude and longitude of solar disc center at 0:00 on the observation day, longitude of solar disc center at the observation time of the day, heliographic latitude and longitude of sunspot groups, types of sunspot groups, maximum area of sunspot and other information are recorded manually. This information can be directly extracted from the handwritten characters.

Automatically recognize handwritten characters in scanned sunspot drawings is a key work to digitalize the collected sunspot information in past. In order to solve this problem, a few Neural Networks algorithms (Appiah et al., 2009; Goltsev, 2012), machine