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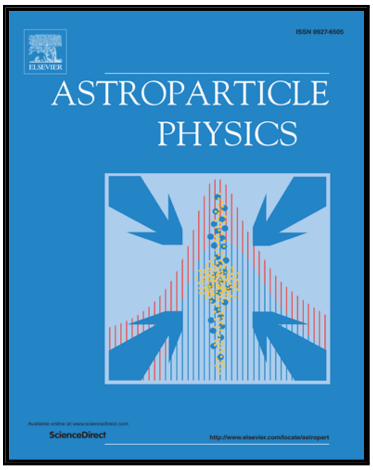

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Particle Identification In Camera Image Sensors Using Computer Vision

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Abstract

We present a deep learning, computer vision algorithm constructed for the purposes of identifying and classifying charged particles in camera image sensors. We apply our algorithm to data collected by the Distributed Electronic Cosmic-ray Observatory (DECO), a global network of smartphones that monitors camera image sensors for the signatures of cosmic rays and other energetic particles, such as those produced by radioactive decays. The algorithm, whose core component is a convolutional neural network, achieves classification performance comparable to human quality across four distinct DECO event topologies. We apply our model to the entire DECO data set and determine a selection that achieves $\geq 90\%$ purity for all event types. In particular, we estimate a purity of 95% when applied to cosmic-ray muons. The automated classification is run on the public DECO data set in real time in order to provide classified particle interaction images to users of the app and other interested members of the public.

Keywords: cosmic rays, deep learning, convolutional neural network, classification, citizen science

1. Introduction

The ubiquity of smartphone devices worldwide has sparked an explosion in the field of distributed sensors; their widespread adoption has effectively instrumented global population centers with a variety of detectors. The CMOS image sensors in modern smartphones are based on similar semiconductor technology to that found in professional telescopes and particle physics detectors, enabling them to detect cosmic rays and other ionizing charged particles. These particles have long been a background nuisance for CCDs used in astronomical cameras [1], however several recent projects including the Distributed Electronic Cosmic-ray Observatory [2] seek to use this background as signal for both scientific and educational purposes. It may be possible for such networks of smartphones to detect extensive air showers created by ultra-high energy cosmic rays (UHECR) above 10^{20} eV, if challenging user density targets are met [3]. This is a powerful and cost-effective way to extend UHECR measurements to higher energies, but there are substantial hurdles to achieving this goal [4]. Since it is also possible to detect local radioactivity with camera sensors [5], networks of smartphones could be used as radiation monitors. More exotic analyses have also been proposed, such as searching for correlated extensive air showers created when an ultra-high-energy photon interacts with the heliosphere [6]. One major hurdle limiting these scientific pursuits is accurate and efficient particle identification, which is necessary to reject the radioactive background for cosmic-ray measurements or vice-versa for radiation measurements. In this paper we describe a computer vision algorithm developed to identify the charged particles detected by camera image sensors. We then apply it to the data set produced by the Distributed Electronic Cosmic-ray Observatory (DECO) [2, 7], the first publicly available cosmic-ray smartphone application.

DECO detects cosmic rays by way of an Android application that began beta testing in October 2012 and was released publicly in September 2014. DECO is designed to detect ionizing radiation that traverses silicon image sensors in smartphones. The resulting dataset consists of images recorded by users worldwide (Figure 1) that contain evidence of charged particle interactions. Due to the diverse ecosystem of Android phones on the market, the systematic variation in data taking conditions, and the variety of particle event morphologies, classification of DECO events presents a unique challenge. Our initial work using straight cuts to classify events in the highly heterogeneous dataset was moderately successful in classifying some event types, but identifying a cosmic-ray muon sample with high purity proved challenging. We present a computer vision algorithm based on a convolutional neural network for classifying DECO events. Additional cosmic-ray cell phones apps mentioned above could also benefit from the approach described here. We presented initial results from our CNN classification in [8]. More recently, during preparation of this paper, [9] appeared and describes a CNN algorithm intended for use as an online cosmic-ray muon trigger.

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