Research Plan

Title: Astronomy Will Not Trail Off: Novel Methods for Removing Satellite Trails From Celestial Images

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a. RATIONALE

SpaceX plans to launch up to 42,000 satellites into orbit in support of Starlink, its high speed internet network which will provide high speed internet to any location on Earth (Bowler, 2019). Astronomers are deeply concerned about the impact of these satellites on astronomical observations, and astronomy research itself (Siegel, 2019). Indeed, some have predicted that the Starlink network will be the "end of Astronomy" (Hall, 2019). The International Astronomical Union (IAU) views the night sky as "a resource for all of humanity" (Bartels, 2019). The American Astronomical Society has engaged SpaceX in efforts to mitigate the effects of such satellites, but remains concerned:

> *The American Astronomical Society notes with concern the impending deployment of very large constellations of satellites into Earth orbit. The number of such satellites is projected to grow into the tens of thousands over the next several years, creating the potential for substantial adverse impacts to ground- and space-based astronomy. These impacts could include significant disruption of optical and near-infrared observations by direct detection of satellites in reflected and emitted light.* ("US astronomers speak on SpaceX Starlink satellites," 2019)

The present research proposes to mitigate the effects of satellite trails by developing and implementing novel algorithms for detecting satellite trails in images and removing these trails.

b. RESEARCH QUESTION(S), HYPOTHESIS(ES), ENGINEERING GOAL(S), EXPECTED OUTCOMES

Research Question

How can the impact of satellite trails on earth-based astronomical research and imaging be mitigated?

Hypothesis
If satellite trails can be accurately identified and removed from night sky images without adversely affecting the photometry of stars near or under the satellite trails, then the effects of satellite trails on earth-based astronomy research will be significantly reduced.

Goals

- to develop software that will rapidly identify and remove satellite trails from images while preserving star brightness;
- to develop software that automatically identifies and removes satellite trails on multiple images;
- to develop deep learning convolutional neural networks trained using stochastic gradient descent to automatically detect the presence of satellite trails in images for rapid removal of satellite trails;
- to quantify the extent of preservation of photometry from images having satellite trails removed via the developed software; and
- to investigate the effects of satellite wobble on satellite trail identification and fitting, and to address these effects.

The overall goal is to provide an application that automatically removes satellite trails from multiple images while maintaining the photometry of stars effected by the satellite trails. This will significantly mitigate the effects of the Starlink satellite network on ground-based astronomical research and observations.

Expected Outcome
The expected outcome is an application that removes satellite trails from night sky images and maintains photometry within the image.

c. PROCEDURES, RISK AND SAFETY, DATA ANALYSIS

Procedures

- Existing line fitting programs will be analyzed to determine their suitability for use in satellite trail identification.
- If existing line fitting programs are unsuitable (e.g., insufficiently accurate at fitting satellite trails to allow removal of the trails with minimal error), novel line fitting algorithms will be developed, coded using Python, and tested.
- Novel algorithms will be developed, coded using Python, and analyzed for accuracy of removal of visual evidence of satellite trails while preserving photometric integrity of stars within the image.
- Colleagues and observatories will be contacted to obtain images with and without satellite trails for testing, including the Martz Observatory in Frewsburg, New York.

- Deep learning convolutional neural networks will be formulated and trained using stochastic gradient descent with momentum to identify satellite trails within images.

Mentor Role
The mentor will provide access to additional night sky images with and without satellite trails, and will provide guidance on software packages for determining photometry in night sky images.

Risk and Safety
There are no risk or safety issues.

Data Analysis
Images of the same location in the night sky will be obtained with a satellite trail (the "satellite-trail-containing image") and without satellite trails (the "satellite-trail-free image"). The satellite trail will be removed from the satellite-trail-containing image using the novel methods to be developed, thereby creating a "satellite-trail-removed image." The satellite-trail-removed image will be visually compared to the satellite-trail-free image to determine visual accuracy of the satellite trail removal methods. Photometry calculations will be performed on the satellite-trail-removed image and the satellite-trail-free image to determine the level to which photometry is preserved in the satellite-trail-removed image.

Proposed Dates
Start date: July 5, 2019 End Date: December 31, 2019

d. BIBLIOGRAPHY

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NO ADDENDUMS EXIST