Comparing eyewitness-derived trajectories of bright meteors to ground truth data

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Abstract

The NASA Meteoroid Environment Office is a US government agency tasked with analyzing meteors of public interest. When queried about a meteor observed over the United States, the MEO must respond with a characterization of the trajectory, orbit, and size within a few hours. If the event is outside meteor network coverage and there is no imagery recorded by the public, a timely assessment can be difficult if not impossible. In this situation, visual reports made by eyewitnesses may be the only resource available. This has led to the development of a tool to quickly calculate crude meteor trajectories from eyewitness reports made to the American Meteor Society (1). A description of the tool, example case studies, and a comparison to ground truth data observed by the NASA All Sky Fireball Network (2) are presented.

Goals

(1) Describe the background and motivation for this project.
(2) Describe the ground truth data and the eyewitness data and how matches between them were identified.
(3) Describe the tool used to calculate crude meteor trajectories from eyewitness reports.
(4) Compare eyewitness-derived trajectories to ground truth data observed by the NASA All Sky Fireball Network, including example cases, and characterize tool performance.

Background

MEO Tasks
- Characterize meteors of public interest.
- Report characterization to the US government.

The NASA Meteoroid Environment Office (MEO) is the only US government agency tasked with analyzing meteors of public interest. When queried about a meteor observed over the United States, the MEO must respond with a characterization of the trajectory, orbit, and size within a few hours.

Typical Data/Tools
- Meteor networks
- Public recordings
- Using observations from meteor networks like the NASA All Sky Fireball Network (2) such a characterisation is often easy. If found, visual reports made by the public and/or eyewitnesses can be used to roughly analyze a meteor if the camera’s location can be identified and its imagery calibrated.

Motivation

Problems
- Meteor is outside meteor network coverage.
- Public recordings not found or cannot be calibrated.

If the event is outside meteor network coverage, if an insufficient number of videos are found or if the imagery cannot be geolocated or calibrated, a timely assessment is difficult if not impossible.

Solutions
- Make use of eyewitness reports.
- Create a tool for characterizing meteor tracks from reports.

Visual reports made by eyewitnesses may be the only resource available. This has led to the development of a tool to quickly calculate crude meteor trajectories from eyewitness reports made to the American Meteor Society (1).

Data Sources

Two data sources were used for this work. Meteor data, taken as “ground truth,” was taken from the NASA All Sky Fireball Network. Eyewitness reports came from the website of the AMS. Matches between data sources were identified temporally and spatially.

Ground truth data: NASA All Sky Fireball Network

Purpose
- Network of 15 cameras set up to observe bright meteors caused by cm-sized meteoroids in 2008

Organization
- NASA MEO

Equipment
- Water 9022M Ultra HD video cameras (30fps), 2 mm f/1.4 lenses, GPS receiver, Linus computer

Software
- Automated meteor detection and analysis using AXIS G133, 43 trajectory and orbit analysis via Coprahe (3) and Borsovich (4), manual analysis using METAL (5) and SMETS (6)

Eyewitness data: Website of the AMS

Purpose
- Promote meteor research by amateurs and professionally collect reports on meteors

Organization
- American Meteor Society (AMS) Ltd.

Software
- Web application for the collection of eyewitness reports of meteors

Tool Description

The software tool used to quickly calculate crude meteor trajectories from eyewitness report data is described. Its performance was characterized based on the comparison to meteor data.

Inputs
- Meteor data and time
- Eyewitnesses location
- Meteor start/end azimuth and elevation
- Meteor duration
- Eyewitness experience level

Outputs
- Crude meteor trajectory (start position)
- Crude average speed
- Map of meteor ground track and eyewitness locations

Methodology

(1) Identify eyewitness reports of interest from the AMS website
(2) Import eyewitness reports
(3) Remove outliers
(4) Fill in missing data
(5) Remove reports with missing data
(6) Calculate start/end sightlines for each observer
(7) Find a model track that minimizes the error for all observations using a distance error metric (track 1)
(8) Identify and remove outliers with a large standard deviations
(9) Refit the model track (track 2)

Performance Characterization

The tool was used to compare meteor data observed by the NASA All Sky Fireball Network on the basis of

- Meteor start/end position
- Apparent radiant
- Average speed
- Average distance error, 1/2 x /y

Results

The trajectory tool was run on the 33 cases of eyewitness reports that had matching meteor observations from the NASA All Sky Fireball Network. Below are four example cases: two with good results and two with poor results. Given for each case are a model ground track, a satellite-like, and an image with a table for errors for the eyewitness-derived trajectory solutions.

Example cases: Good results

Example cases: Poor results

Example cases: Poor results

Example cases: Poor results

Summary and Future Work

To quickly characterize meteor tracks of public interest observed outside the coverage of meteor networks, a tool was created to calculate meteor trajectories based on eyewitness reports. The performance of the tool was evaluated by comparing meteor data collected by the NASA All Sky Fireball Network for 33 cases to eyewitness reports. For two example cases, trajectory solutions per case yielded better eyewitness-derived trajectories.

Areas for future work include:
- Investigate weighting by observer experience level.
- Improve methods for outlier rejection.
- Develop method for estimating confidence.
- Run more test cases.

References

For a list of references, see the full report.

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