INTRODUCING THE FireOwl – DATA PROCESSING SOFTWARE OF THE FINNISH FIREBALL NETWORK

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Introduction

The Finnish Fireball Network (FFN) was established in 2004 due to growing interest in continuous meteor and fireball monitoring. In the current state, the network consists of the 24 active stations with permanent instrumental setup and monitors a surface over Finland and neighbouring areas of about 400.000 km2.

Most of the active stations are run by amateur astronomers. Until recently, the majority of interesting events were reduced in the following days after the registration and the atmospheric trajectories corresponding to the visual path of fireballs were retrieved using the fb_entry program [1] [2].

In this presentation, we describe the new FireOwl software developed for and used by the Finnish Fireball Network. The software includes kernels for image calibration, fireball measurements, visible flight triangulations, dark flight trajectory, and solar system orbit calculation.

Methods

The software is a web application and is written in JavaScript. Therefore all numerical calculations are processed as client-side procedures. Results can be stored in the server for later use. Selected cases are studied more thoroughly and may include: mass computations [3], dark flight simulations [4], search for parent bodies and pre-impact orbit estimate [5].

Images can be calibrated using either polynomial or barrel model [1][2]. Barrel model is expanded with correction terms as

$$r = (1-t)*atan(R/f) + t*(R/f) + k_3*(R/f)^3 + k_5*(R/f)^5 + k_7*(R/f)^7 \quad (1)$$

Polynomial model also requires information about projection type, which can be manually selected (gnomonic, stereographic or equidistant). Polynomial model is simply

$$R = a_1(r) + a_2(r)^2 + \ldots \quad (2)$$

R is an observed radial distance from the image center in pixels and r is either the real or projected angle. Image calibration parameters are:

- Optical direction, az and alt; the direction which the optical system center is pointing at.
- Optical center, x and y ; the optical center in pixels in the scanned image and the origin is at the top left corner of the image.
- Tilt; the rotation of the camera around the optical axis.
- x/y-ratio; equal to 1 if the image is not stretched.
- f; focal length of the barrel-model
- t; barrel-parameter of the barrel-model
- k3, k5, k7; correction parameter for 3rd, 5th and 7th degree of the barrel-model
- a1,a2,a3,...; polynomial terms for corresponding degrees

Results

We demonstrate the usage and capabilities of the software using a prominent example of exceptionally durable fireball observed in Northern Scandinavia. The fireball entered the atmosphere at 2020-09-07 T20:03:34Z and was visible for 26 seconds. In addition to FFN data, visual observations of the fireball were reported by 36 observers around Finland to the Ursa's Taivaanvahti service https://www.taivaanvahti.fi.

We use image observations from the two locations and one video observation in order to define the luminous flight trajectory. These observations are found:

- Haukipudas (https://www.taivaanvahti.fi/observations/show/93529)
- Tohmajärvi (https://www.taivaanvahti.fi/observations/show/93511)
- Tampere (https://www.taivaanvahti.fi/observations/show/93504)

We calibrate cameras and measure the beginning and the end points for Haukipudas and Tohmajärvi. Video obtained from Tampere is also inspected by frames to retrieve velocity distribution of the fireball. Measurements are shown in Table 1.

We use dz-correction [6] to retrieve flight trajectory with good accuracy. The reconstructed flight trajectory together with velocity curve are used to inversely solve for the best fitting mass of the meteoroid and its pre-impact solar system orbit. We conclude that this showcase does not turn out to be a probable meteorite-producing candidate according to numerical integration and the alpha-beta criterion [7] [8] [9].

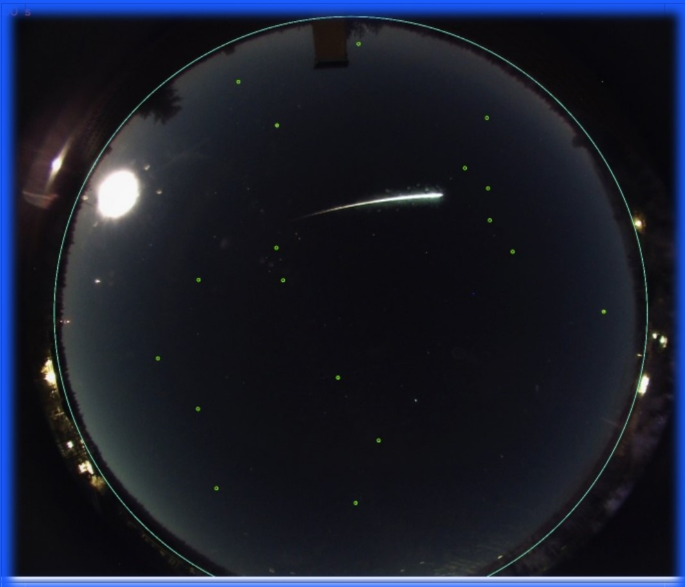

Figure 1. Calibration window for Haukipudas. Green dots are 18 stars used in calibration. Cyan circle is the mathematical horizon after calibration.

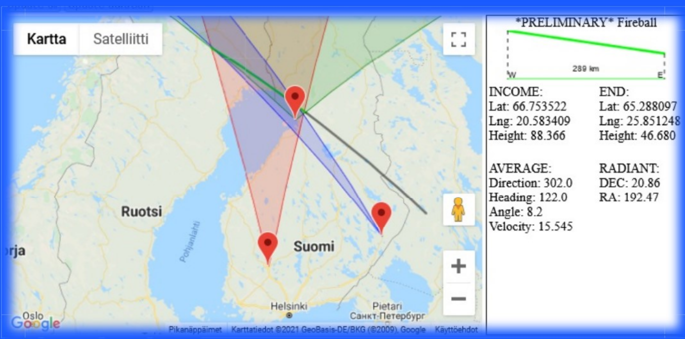

Figure 2. Triangulation using three observations. Preliminary fireball data is shown in the right panel. This gives a quick look into the unique fireball events.

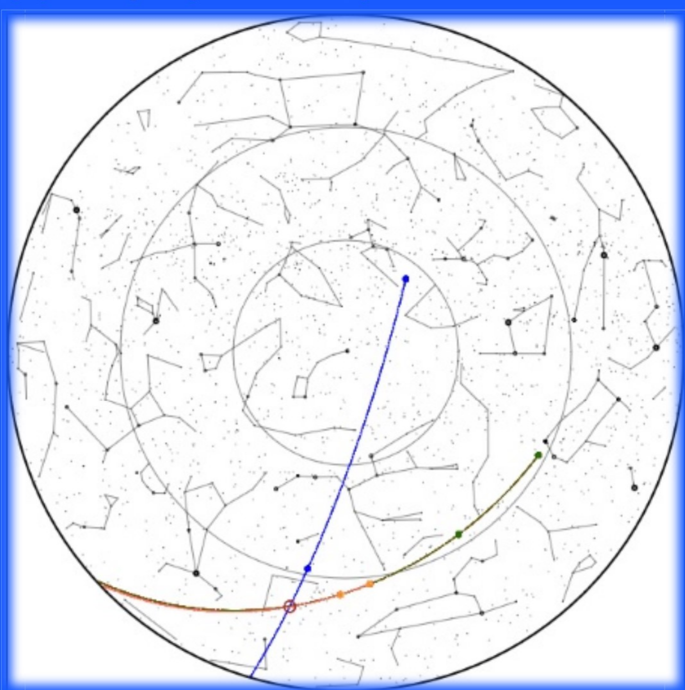

Figure 3. Bipolar traces of the fireball are plotted onto the northern sky chart. This is essential in order to define accuracy of the calibrations. All used observations should have the same intersection point which equals the radiant point. In this rare case Tampere and Onkamo share exactly the same plane and therefore are unsuitable for defining the trajectory without the third or more observations.

Conclusions

Fireowl is a quick and accurate tool for fireball analysis. It is flexible for calibrating casual images taken by random photographers. Fireowl is also easy to use with any platform due to web origin and open source code. So far Fireowl is restricted for usage by Finnish Fireball Network. Future prospects are to develop automated D-criterion tools using NASA Small-Body Database and IAU Minor Planet Center archives.

Acknowledgements

We are in deep gratitude to Esko Lyytinen for his contribution to Fireowl. We honor the memory of Esko. We thank the members of Finnish Fireball Network for assisting and testing FireOwl during development.

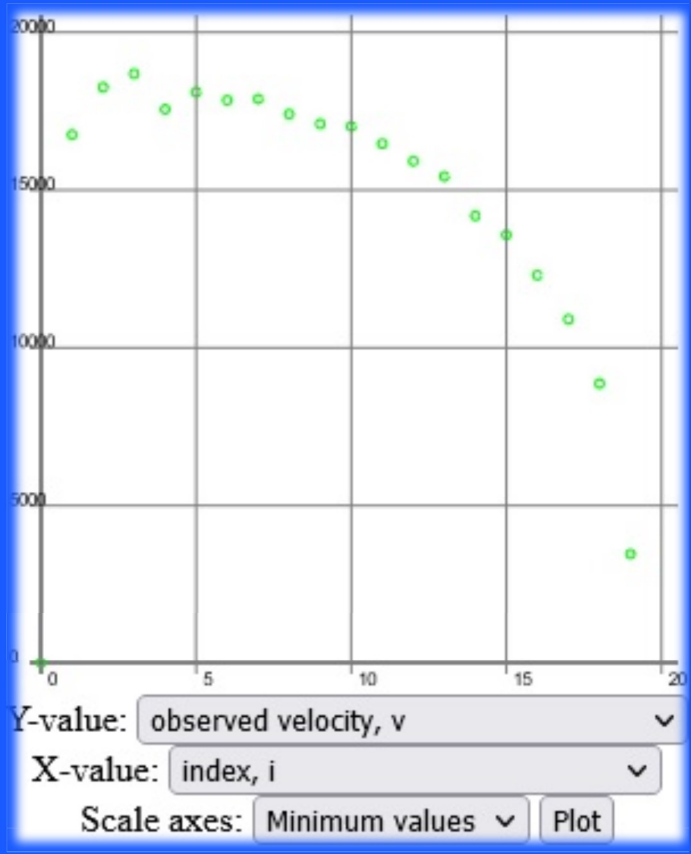

Figure 4. Video observations can be used for defining velocity distribution. Here we have sparsed Tampere video into 19 frames in order to study velocity curve more accurately.

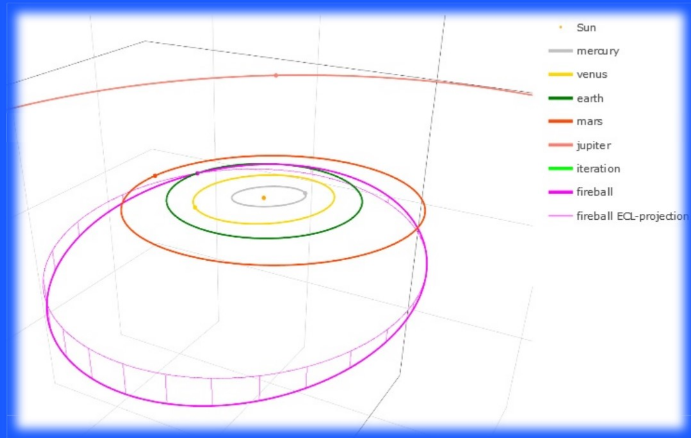

Figure 5. Using the entry velocity and entry point we can numerically iterate meteoroid out of Earth-Moon gravitational system and then solve the pre-entry solar system orbit. Orbital parameters are:
a = 2.069, e = 0.596, i = 5.153, long. peri. = 288.459, long. node. = 165.415, period = 2.975 y, time of perihelion = 2020-07-30 T 00:12:38.602 Z,

Station	Station coordinates	Point	Azimuth (deg)	Altitude (deg) (corrected)	δz
Tampere	61.5118, 23.7931, 171m	Begin	346.462	5.501	197
		End	11.913	4.149	300
Tohmajärvi	62.2843, 30.0679, 89m	Begin	321.945	4.380	263
		End	328.916	4.890	225
Haukipudas	65.1294, 25.2905, 9m	Begin	312.396	16.193	29
		End	50.762	56.517	3

Table 1. Fireball is measured from all three observations. Values are used in triangulation of the fireball. δz [6] in the last column is the artificial lift of the observing site to reduce the error in refraction.

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