Short paper

A modern video meteor detection system and network – *Overview and typical costs*

William Stewart & Alex R. Pratt

Introduction

During the past decade video technology has been used by groups in Japan,[1] Continental Europe,[2] the United Kingdom[3] and, more recently, the United States[4] to record hundreds of thousands of meteors. What makes these recordings stand out is that they were carried out by coordinated networks of observers, and that in many cases each event was captured from multiple locations. Through the use of triangulation the velocity, trajectory and orbit of the parent meteoroid has been derived and from this our knowledge of the major showers and many of the minor showers has significantly improved. This has helped refine the mathematical models of the streams and has led to better predictions of how a particular shower will behave in a given year.

However there is still much work to be done. Of the 493 suspected showers on the International Astronomical Union's Meteor Data Centre (IAU MDC),[5] only 95 have 'Established' status. Proving the existence of a shower or differentiating between showers with similar radiants requires additional observations. As technology improves and prices fall, amateur observers, working in coordinated networks, can make increasingly precise contributions. This paper provides an overview of a typical video-based meteor detection system, requirements for an effective network and looks to the future of how this type of work may progress.

The camera

Video observations obviously require a video camera and for a number of years models have been available that can capture excellent live views of the night sky without the need for image-intensifier technology (thus reducing cost and complexity). Live video (as opposed to a camera that integrates an image over a period of a few seconds or minutes) enables not only a precise measure of the meteor velocity but also an accurate time for when the event occurred, key requirements when determining the original orbit of the meteoroid.

For many years the camera of choice has been the Watec 902H and enhancements to the model have ensured this continues to be the case. It is sensitive, robust, readily available with $^1/_2$-inch and $^1/_3$-inch format sensors and provides 25 frames per second at a resolution of 752×582. New units retail for around £300 while secondhand units can be purchased online for under £125. Other cameras are available such as the Mintron 12V6HC-EX (£269) or the FSAN KPF 131 HR for around £60. The latter has reduced sensitivity (0.002 lx compared to the 0.0001 lx of the Watec) and a lower resolution (582×500).

Figure 1. The three cameras of the Ravensmoor node permanently affixed to the gable end of a brick building. The unit on the left faces southeast, the middle one northeast while that on the right faces north. Note the black spacer block on the first two units between the camera housing and the mounting bracket. This modification was required in order to allow the appropriate elevation to be achieved without the rear of the housings fouling on the horizontal support bracket.

High Definition (HD) video cameras with sufficient sensitivity are becoming available and experiments using the video mode of digital SLR cameras, as well as cameras such as the PointGrey Grasshopper series are, at the time of writing, ongoing. The higher resolution of these devices enables a more precise measure of the angular position on the sky, which in turn leads to reduced uncertainty when determining the orbital parameters. These options are however relatively expensive (in excess of £1000) and, being new technology, units have not yet filtered down to the secondhand market.

The lens

A c-mount lens that covers a reasonable area of the sky is required to focus the light into the camera. It is not possible to know in advance where a meteor will occur and so the natural instinct is to use a wide-angle lens to maximise the chance of a capture. However, this will only detect bright meteors, whereas a lens with a longer focal length, while having a smaller field of view (FOV), will detect fainter meteors.

Typically lenses with a focal length in the range 3.8mm to 12mm are employed, yielding a respective FOV of 80° to 20°. A longer focal length lens is better suited to a suburban location that suf-

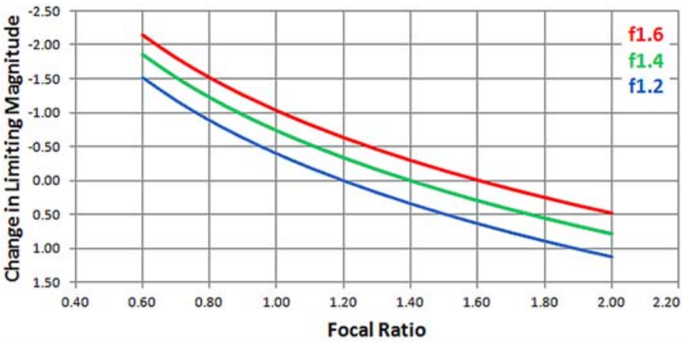

Figure 2. Variation in limiting magnitude when changing focal ratio for a given focal length lens.

fers from light pollution and has, due to local obstructions, limited options for where the camera can be pointed. Such lenses yield higher quality data leading to more precisely determined orbits. Lenses are designed for cameras with a particular sensor size and so using, for example, a lens intended for a $^1/_3$" sensor on a $^1/_2$" sensor camera will result in vignetting and significant distortion/degradation of the image at the edge of the FOV.

Another consideration is the focal ratio or 'speed' of the lens: f/1.2 or better will give good results. The sensitivity of camera sensors has now increased to such an extent that manufacturers no longer have demand for ultra fast lenses. Some years ago Computar halted production of a series of aspherical (well corrected) f/0.8 lenses with focal lengths of 3.8mm, 6mm, 8mm and 12mm, as did Pentax with their series that had focal ratios of f/0.95 or better. Although they occasionally appear on Internet auction sites, availability continues to diminish and they often command high prices – expect to pay in excess of £80.

Lenses of f/1.2, 1.4 and 1.6 are readily available and fast lenses are still produced by manufacturers such as Computar (TG3Z2910FCS-IR), Tokina (TVR0398DCIR) and Fujinon (YV2.8×2.8LA-SA2) – expect to pay around £50. These are often zoom lenses where the focal ratio increases with the focal length and it is important to determine actual speed for a given focal length.

Figure 2 shows how the limiting magnitude changes with focal ratio for a given focal length. As can be seen, a lens of a particular focal length operating at f/1.0 will detect meteors a full magnitude fainter than one of the same focal length operating at f/1.6. The typical meteor population index (defined as the ratio between the number of meteors of magnitude m+1 and the number of meteors of magnitude m) is in the range 2.5 to 3.0[6] and so the faster lens can make the difference between detecting 20 meteors per night and detecting 50 –60.

The Video Meteor Database of the International Meteor Organisation[7] provides a good overview of what users typically achieve for a given focal length/focal ratio. Whatever is chosen, the camera and lens combination must be capable of detecting stars down to magnitude +3 to allow accurate astrometry to be performed on the resultant capture. Due to the transient nature of meteors and the detection/triggering capabilities of the software, the faintest detected meteors are typically 1 magnitude brighter than the stellar limiting magnitude.

Data system & software

The capture software is not processor intensive; hence typical desktop PCs from the early 2000s running Windows XP will suffice. The Ravensmoor node of NEMETODE,[8] a UK-based meteor observation network operated by members of the BAA Meteor Section, utilises IBM ThinkCentre M51 3.2GHz P4 HT units which can be picked up for around £40. Typical CPU load is around 20% and the only modification from the standard specification has been to add additional RAM and a 300GB hard disk drive (HDD).

There are a number of choices available for the acquisition software and these determine the choice of interface card to allow the video signal to be streamed into the PC. The days of recording an entire video stream of the night sky, then spending an equal (or greater) amount of time visually examining the video for meteors, then manually estimating magnitude and radiant are, thankfully, over.

Modern systems use tuneable motion detection algorithms, whereby the video stream is continuously read into a memory buffer and only those sequences that contain movement are saved as discrete clips to the HDD for later analysis. Sequences in the buffer containing no movement are discarded. Analysis of the clips is automated with minimal user interaction required.

The first software option is *MetRec* (*Meteor Recogniser*).[9] This is a well-established and widely used program that not only has excellent motion detection capabilities but also performs real-time monitoring of local seeing conditions. It accomplishes this by periodically (every 60s) comparing the pixel values of known stars within the FOV against the actual magnitudes for those stars. From this it then estimates and logs local atmospheric transparency. Reliable 'meteor flux' data that is analogous to that obtained by traditional visual observation methods can therefore be inferred, as can the effective collection area.

In addition the software determines, on the fly, meteor brightness, velocity and equatorial coordinates and assigns shower association based on the working list of the International Meteor Organisation.[10] Results can be uploaded to the servers of the Virtual Meteor Observatory which in turn plots the temporal change in ZHR.[11] The software is freely available from the authors' website but requires the use of a particular type of frame grabber card (Matrox Meteor) which is no longer produced. Secondhand units are available but these typically cost around £125.

MetRec is a good choice for observers who operate as 'single stations' as opposed to part of a coordinated network. Although the software does not support triangulation, characteristics such as radiant, pre-atmospheric entry velocity, activity interval and profile can be derived through the application of sophisticated statistical algorithms to large sets of *MetRec* data.[12]

Another option is *SonotaCo*'s *UFO* suite.[1] DO NOT be put off by the name as this is a set of highly capable programs designed for capturing and analysing any object moving through the atmosphere: while primarily designed for meteors, *UFO Capture* software has been used to detect other atmospheric phenomena such as sprites above lightning storms.

Like *MetRec* this software is well established and widely used. It has a Windows interface, multiple configurable options and has recently had HD capability added. It does not support real-time monitoring of local seeing conditions nor does it perform the analysis (magnitude, speed, position, radiant and shower association) on the fly – these are performed later using a separate program called *UFO Analyser*.

The greatest strength however is the capability of a third programme called *UFO Orbit* which takes the analysed data from

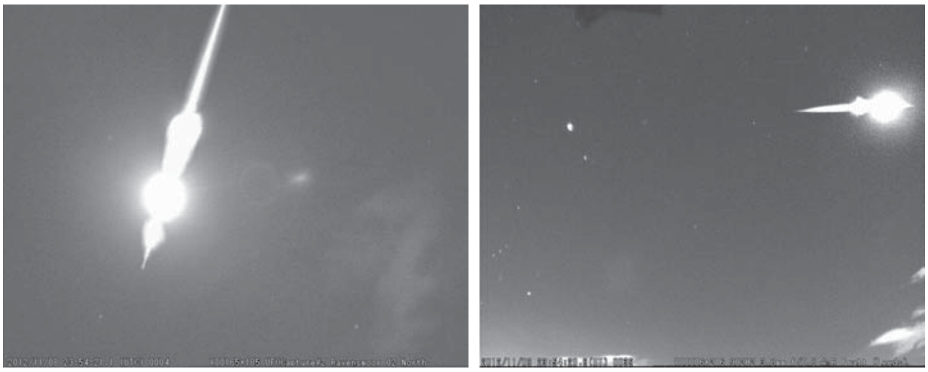

Figure 3. Northern Taurid fireball from 23:54:20 UTC, 2012 Nov 8, imaged by NEMETODE network cameras from Ravensmoor *(left)* and Leeds *(right).*

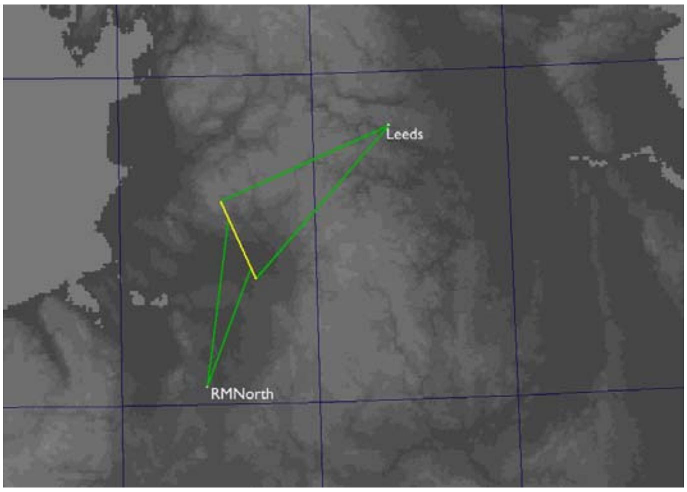

Figure 4. The triangulated ground track of the fireball captured in Figure 3.

individual observers and automatically determines parameters for the radiant, velocity, trajectory and orbit. This can be reliably performed for individual events whereas *MetRec*'s statistical approach requires large datasets. Depending on exchange rates, the software licence for *UFO Capture* costs around £125 (following an initial, free, 30 day trial period). The other two programmes (*UFO Analyser* and *UFO Orbit*) are free.

The software interfaces with readily available TV cards: the NEMETODE network make use of Osprey 210 Video Capture cards, the cost of which has fallen significantly in recent years – new ones can be purchased online for under £30. Cheaper TV cards are available though in the authors' experience, quality is variable with some contributing to lost frames. USB-based devices such as the ClimaxDigital unit (£20) have also been successfully tried.

The *UFO* suite is a good choice for observers operating as part of a network who take steps to ensure common volumes of the meteoric layer are simultaneously observed. Smaller networks can obtain good results from the outset without waiting for a large (multi-year) dataset to be accumulated.

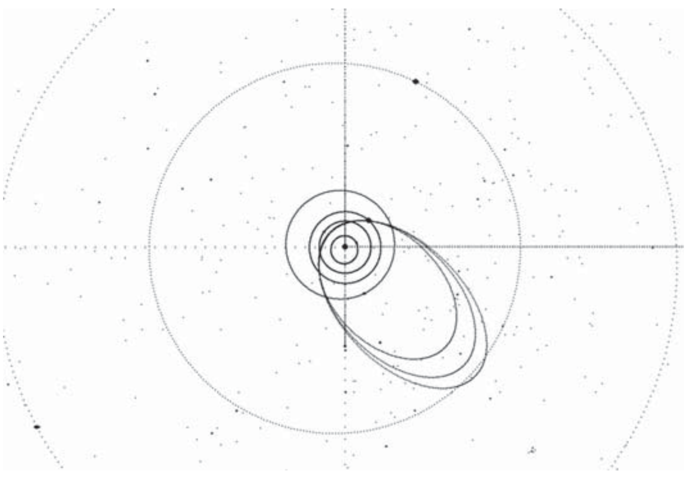

Figure 5. Triangulated orbits for the meteor captured in Figure 3.

Power

Initially a laptop-style power supply was used to convert 230V AC to 12V DC (to power the camera and the iris on the lens) though the more permanent installation at Ravensmoor has now switched to a dedicated, higher current, enclosed power supply that supports three camera systems. The Leeds node of NEMETODE uses 12V DC transformer plugs.

Costs ... and automation

A budget of around £450 will purchase a highly capable system that can generate good scientific results. This is not a trivial amount of money but nor is it an outrageous one. As ever one has to weigh up the pros and cons of cost (initial outlay) versus benefit (how much will it be used?)

A significant attraction of a video-based meteor detection system is the ease with which much of the data collection can be automated. Many aspects of astronomy require confidence that skies will be clear for a number of hours before attempts are made to set up equipment, sacrifice a few hours sleep, make the observations then pack everything away. However with minimal additional financial outlay a meteor system can be made permanent and configured to run for multiple consecutive nights (irrespective of forecast conditions) with no user intervention whatsoever. While the user sleeps, data collected during a 30-minute break in an otherwise cloudy night contribute to the overall picture.

The first step is a weatherproof enclosure for the camera and lens. Competent individuals have made their own using lengths of drainpipe and perspex covers, but with commercial (CCTV) units that include mounting brackets and incorporate a heater to demist the front window available for around £50, users may decide that the time taken to manufacture and the risk of failure is not worth the financial saving. Commercial units are typically designed to point down instead of up, and hence what may provide good protection from the elements in one orientation may not work in another. NEMETODE observers use units from MAP Security sourced via eBay – search on '*ebay map security cctv enclosure*' – and have found them to be excellent.

Next, a mechanism to automatically switch the camera and lens iris on and off is required. This can be as simple as powering the 230V AC to 12V DC power supply via a mains timeswitch of the type that is often used to automatically switch lights on and off. These are readily available for under £5 from electrical or DIY stores, and presetting them to activate/deactivate at the time of sunset and sunrise is a straightforward exercise. Bright sunlight focused on to the energised sensor of a sensitive camera is to be avoided.

These times will need to be adjusted during the course of the year in line with changes in local sunset/sunrise times; this can be inconvenient and so other potential solutions include operating the power supply in line with a light sensor or, as in the case of the NEMETODE Ravensmoor node, making use of a Theben SEL170 timeswitch, a device that takes account of the date and observer's location and automatically changes the switching time. These are around £90 new but do appear regularly on eBay for under £40.

Thus a modest increase to the budget can significantly enhance utilisation and help justify the initial outlay. Over the first year, assuming less than 15% of the hours of darkness are clear, the cost works out at under £1 per usable hour.

Future prospects

In the coming decade technological improvements such as affordable low-light sensitive HD cameras coupled with improved software will allow for fainter (and hence more) meteors to be detected with increasing levels of precision. This improves the chances of confirming (or disproving) many suspected showers, while at the same time refining the set of orbital parameters for shower streams and the filaments within them. Enhanced coordination is essential and while it is clear that the technology exists and is being developed, there are still vast sections of the globe where there is little or no monitoring. Key events are therefore missed due to daylight or inclement weather.

Through this paper the authors hope to encourage readers not only to submit their observations to the BAA Meteor Section, but also to consider whether they would like to take the plunge with video technology. Modern software now handles many of the tasks that were burdensome to the early pioneers, and automation allows observations to fit in with modern lifestyles. The multiple methods of sharing data that are now available also make network participation a realistic prospect for many.

So what are you waiting for?

Acknowledgments

The authors are indebted to the many individuals, too numerous to mention, who have already walked this path, developed and pioneered the technology and shared their results with others. In addition, the NEMETODE team has learned much from each other, particularly since the start of their dual station collaboration. Many of these lessons are outside the scope of this paper but may be of value to those who are just setting out: these are documented in a previous paper[13] and on the authors' website.[8]

Address: c/o British Astronomical Association, Burlington House, Piccadilly, London W1J 0DU.
ARP: arp@nemetode.org
WS: ws@nemetode.org

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