Photographic Reconstruction of Sun's Position from a Driver's Perspective

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Summary

This paper deals with the practical investigation, surveying and two dimensional photogrammetry techniques associated with identifying and plotting the sun's relative position on a series of collision site photographs, so as to demonstrate its true position in the sky as would have been observed by an approaching driver, or as the case may be, from the perspective of a witness.

Introduction

The SUN's position, when low in the sky, is often alleged to be a contributing factor in the cause of many vehicle accidents. Normally, when the sun's position is in issue, an investigator (in Australia) would ordinarily commission a surveyor from the Australian Surveying and Land Information Group (AUSLIG), to provide the coordinates of the sun's position from the collision site, in the form of an 'expert certificate'. How then can we, as accident investigators, take this important information to the next dimension, by accurately and clearly demonstrating to a court, within a photograph, the sun's relative position in the sky to that of a driver's approach path at the reported time and date of a collision.

During this presentation, it is intended to identify, explain and demonstrate the means available for investigators to easily determine the collision site's latitude and longitude on the earth's surface. Following this, the time, date and local time zones will be discussed to prepare the investigator with the necessary information with which to determine the sun's true position in the sky at the time of the collision.

Simple map reading, surveying and photography techniques will be discussed and demonstrated, in order to identify and establish a series of on-site control points (with horizontal and vertical datums) from which photographs can be exposed for later photogrammetry analysis of the sun's position. Two dimensional photogrammetry considerations will be discussed and demonstrated in order to scale photographs for vertical and horizontal angular measurement, which will be concluded with the identification of the sun's position on the photograph, relative to the camera position.

Location on Earth

In preparation of completing this task, the investigator's first job is to identify whereabouts on the earth's surface the collision occurred. Easy you might say; its at the intersection of Smith and George Streets, Downtown. Well, that might be OK for the local Traffic Sergeant, however we need to go that next step and find out what the actual geographical coordinates are for the collision site, that is, the position on earth with reference to its latitude and longitude. With these two reference points, we can define any location on the earth's surface.

Latitude

Latitude, is the angular distance north or south of the equator to a point on the earth, which can be expressed in degrees (°) minutes (') and seconds (”); or alternatively in decimal degrees. See figure 1.

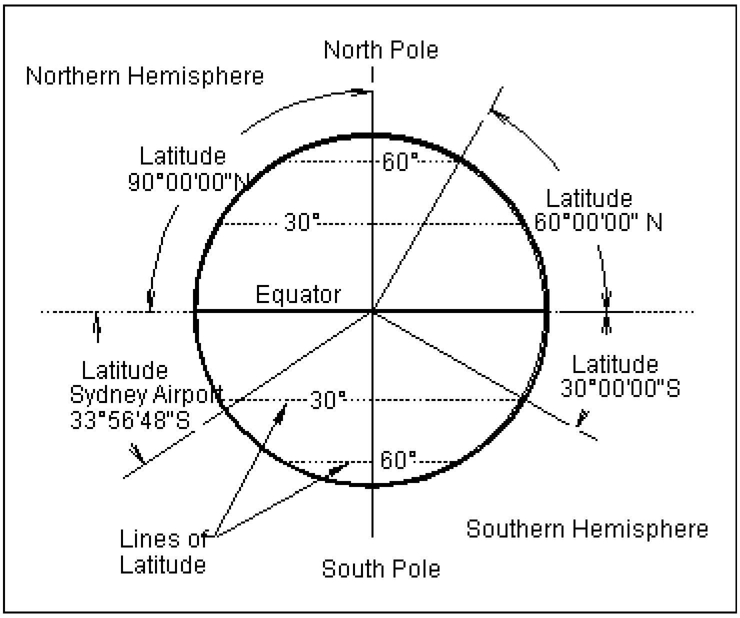

Figure 1. Latitude diagram

The standard of accuracy for this level of investigation need only be to the nearest minute of arc.

Australia is located in the southern hemisphere and its latitudes lie between 10° 41' S (near top of Cape York Peninsula - QLD), and 43° 39' S (southern edge of Tasmania)

The latitude for a specific aviation navigation point within Sydney Airport can be expressed as 33° 57' south or 33.95° south.

Longitude

Longitude is the angular distance east or west from The Meridian of Greenwich to that of another place on the earth’s surface.

Greenwich is located near London, England and was the original site of the Royal Observatory, founded in 1675 by King Charles II. The Greenwich Meridian was internationally adopted in 1884 as the zero of longitude and it is the line from which all other lines of longitude are measured. It is an imaginary line which runs from the North Pole to the South Pole, passing through the main telescope in the Royal Observatory (which, incidently is located at a latitude of 51°28' North).

Australian longitudes lie between 113°09'E and 153°39'E, so with reference to the sphere shown in figure 2, we are located on the right-hand side and to the rear (out of view).

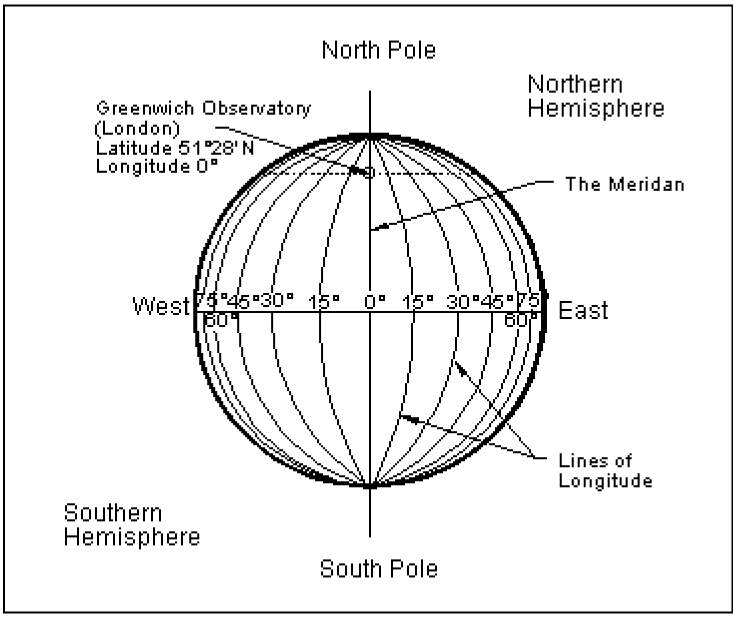

Figure 2. Longitude diagram

Identification of Latitude and Longitude

The latitude and longitude of a collision site can be obtained quite easily in a number of different ways. For our purposes, the two easiest and most efficient methods to use is a map or hand-held global positioning system (GPS). If you don't have access to either, try calling AUSLIG by telephone or visit their home page on the internet at www.auslig.gov.au/mapping/names/names.htm where you can do a locality/name search for your geographical coordinates. (More on this internet site later).

Maps. If you have access to and know how to read an appropriate topographical or aviation map, the site's geographical coordinates can be measured straight from the lines of latitude and longitude published on the map. Aviation maps such as the one illustrated in figure 3, are better suited for this use as they are easily obtained from any local pilot shop, they are simple to read with accurate graduations to the nearest minute of arc, they display current information on magnetic variation and are relatively inexpensive.

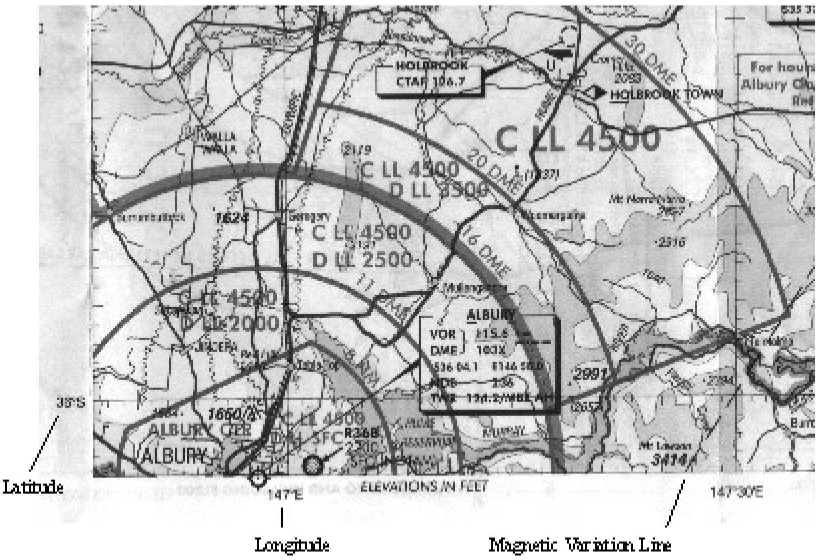

Figure 3. Portion of Aviation Map

GPS. Global Positioning Systems are also quite inexpensive, (although not as cheap as maps), particularly models used for bush walking which can be purchased for under A$200.00. They are very accurate instruments when used correctly and are well suited for this type of work. In fact, some police accident investigation sections in Australia already use GPS for site identification for statistical purposes.

These instruments of course have many other useful applications, one of which is the identification of sunrise and sunset times for a particular location. All GPS can directly display current latitude and longitude, however the user must become familiar with the operation of the GPS unit and be aware of the instrument's limitations and errors.

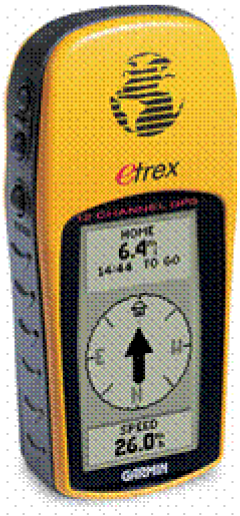

Figure 4. GPS

Time, Date and Time Zone

In order to calculate the position of the sun in the sky for a particular motor vehicle collision investigation, we need to identify the time and date of the event, and the applicable time zone for the collision site.

Time Zones. In simple terms, the earth rotates 360° every 24 hours, or 15° every hour. Ordinary civil timekeeping throughout the world is divided into 24 different time zones which generally correlate with each standard meridian (15°) of longitude, (see figure 2).

Universal Time. When the Greenwich Meridian was internationally adopted in 1884 as the zero of longitude, it was also adopted as the world time reference point from which all other time zones across the world would be measured. Hence the term Greenwich Mean Time (GMT). Other terms used to describe GMT are, Universal Time Co-ordinated (UTC) or ZULU Time.

Australia falls across three of these time zones. Eastern Australia uses the 150°E meridian which is known as Eastern Standard Time (EST). Because the earth rotates from west to east, EST is 10 hours ahead of GMT (or GMT+10). Central Australia (including Broken Hill in NSW) use the 142°30'E meridian which is known as Central Standard Time (CST), or GMT+9.5 hours. Western Australia uses the 120°E meridian for Western Standard Time (WST), or GMT+8.

Daylight Saving. In those states where daylight saving is applicable during the warmer months (between October and March in Australia), you will need to add an additional hour to your time zone, as the local time zone is put forward by one hour. i.e. EST is then referred to as Eastern Standard Daylight (Saving) Time (EDT), or GMT+11.

Sun Position

Now that we have all this information about the time, date, location and time zone of the applicable crash site, we can go about determining the sun's position in the sky, as would have been observed from the site at the time of the event. (Don't worry, this is the easiest part).

AUSLIG Internet Site. AUSLIG have gone to a lot of trouble to provide the public with a free internet service which does all the necessary calculations for you, which, after you enter the appropriate information, takes about a minute to complete and print. Their site is located at: www.ga.gov.au/nmd/geodesy/astro/smpos.jsp

There are other software programs available such as EZ Cosmos, Skymap or indeed other web sites around the world which will allow you to compute the sun or moon positions for any time, date and place on earth.

The information provided by AUSLIG includes the sun's azimuth, altitude and refraction angles to the nearest minute of arc.

Azimuth and Altitude. Azimuth is the clockwise horizontal angle from true north to the sun. The altitude is the vertical angle from an ideal (level) horizon up to the sun.

Refraction. At sunrise and sunset, refraction of the sun's rays make the sun appear higher in the sky than its true geometric position, by an angle of about ½°. This refraction angle is variable and depends upon atmospheric conditions. As the sun's altitude increases, this refraction angle rapidly decreases.

Site Survey and Photography

We are now ready to conduct a site investigation which will require us to combine some surveying, navigation and photography skills. The best survey equipment to use for this study is a total survey station and stadia, which will give you the greatest accuracy. Other tools that will assist the investigator include a local map, prismatic compass and smart-level. An automatic survey level and stadia are also suitable, however your accuracy will be limited in the horizontal plane to about ½o of arc, which is about equivalent to the diameter of the sun when viewed from the earth. Whatever your method, your survey requires accurate orientation to true north.

Magnetic Variation (MV). If you intend to use a magnetic compass to assist with orientation of your site survey, then you will need to determine the MV of the collision site. MV is the angular difference between true north and magnetic north from an observer's position. The position of the magnetic pole is not fixed and it changes ever so slightly each year. The required information is usually published in the marginal information of most topographical maps and should be noted as being correct for a particular year. You will need to make the appropriate calculations and adjustment for the current year. Current aeronautical Visual Navigation Charts (VNC) are the most convenient maps to use for this purpose, as they are recent and have the lines of MV published across the face of the mapped area.

Magnetic/Azimuth Conversions. Once you have determined the current MV for your location, you must convert your magnetic bearings to true azimuth bearings. To do this you either add or subtract your MV to or from your magnetic bearings.

When magnetic north is to the west of true north (western region of western Australia), you subtract the MV from your magnetic angle to identify the true bearing. Alternatively, when magnetic north is to the east of true north (eastern Australia), you add the MV to your magnetic angle to identify the true bearing.

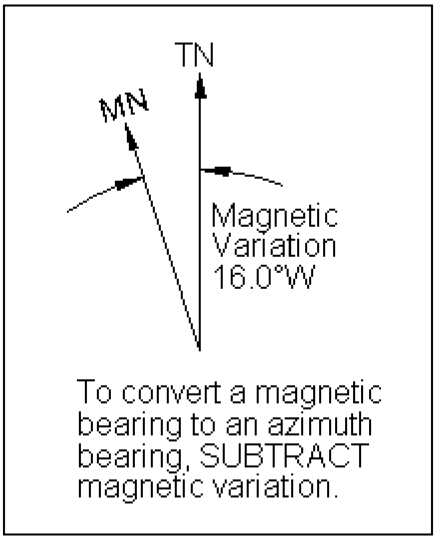

Figure 5. Magnetic variation (west)

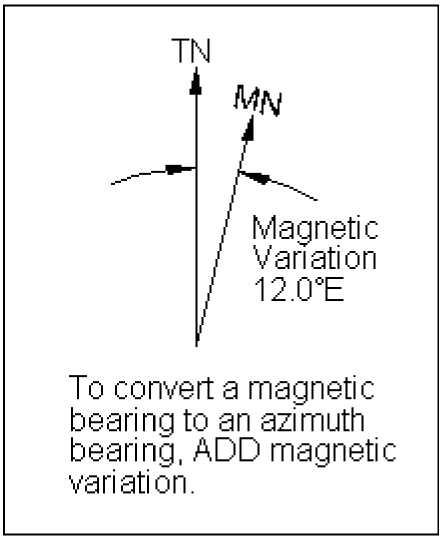

Figure 6. Magnetic variation (east)

Horizontal Reference Points. The first objective in determining the sun's position within a photograph, is to identify, survey and photograph two reference points in the horizontal plane, relative to the camera position (also surveyed). Such points can be permanent site features such as power poles or guide posts, or temporary markers such as traffic bollards. Whatever points are used, they should be located on either side of the sun's computed azimuth angle and within the camera's normal field of view. The true azimuth angles should be measured from the camera position to each of the reference points.

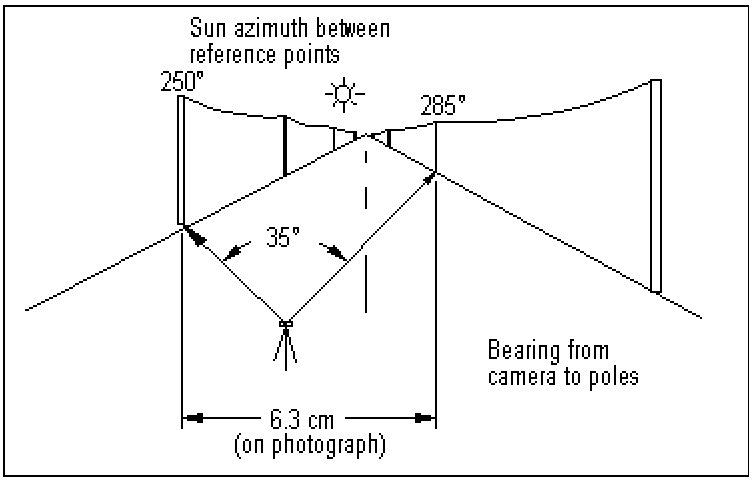

Figure 7. Horizontal Scaling.

Horizontal Angle Scale. The known horizontal angles between camera and reference points are later used with the developed photograph to provide an accurate horizontal angle scale. In figure 7, for example, 6.3 centimetres across the developed photograph would equal 35 degrees of arc in the horizontal plane.

Sun's Horizontal Position. Also, in the above example, if it had been determined from the sun position computations, that the sun's horizontal angle at the time of the collision was 267° 30' (or 267.5°), then it could be concluded from your site inspection that the sun's horizontal angle with respect to this particular camera position, was located about midway between the two reference points.

<u>Vertical Angle Scale.</u> In order to plot the sun's vertical position on the developed photograph, we now require some form of vertical reference in the picture, hence our second objective. We could substitute one of the power poles shown in figure 7 with a stadia survey staff (a large ruler), which we could stand on the edge of the roadway, located reasonably close to the camera so that we could identify units of measurement from the developed photograph. This would then allow us to scale height and therefore vertical angle from the camera position onto the photograph.

To calculate the sun's vertical angle accurately however, we need to identify the horizontal distance between the camera and stadia, and whereabouts on the stadia we should be looking (in the photograph) to observe along the same level as the camera, that being toward an ideal horizon. That is, if we were still on site, whereabouts on the stadia would we tie a string line so that it ran level to the camera lens.

This information can be easily obtained direct from your survey data by identification of the reduced levels (RLs) for both the camera and stadia positions. You will also need to note the height of your camera lens above the road surface. (Say 1.15 metres for a normal car driver). Once we establish these few measurements, we can then apply simple trigonometry to identify how far up the stadia we should look in the photograph, in order to view a certain vertical angle from the camera lens. i.e. using the tan rule we find that the opposite = tanΘ (adjacent).

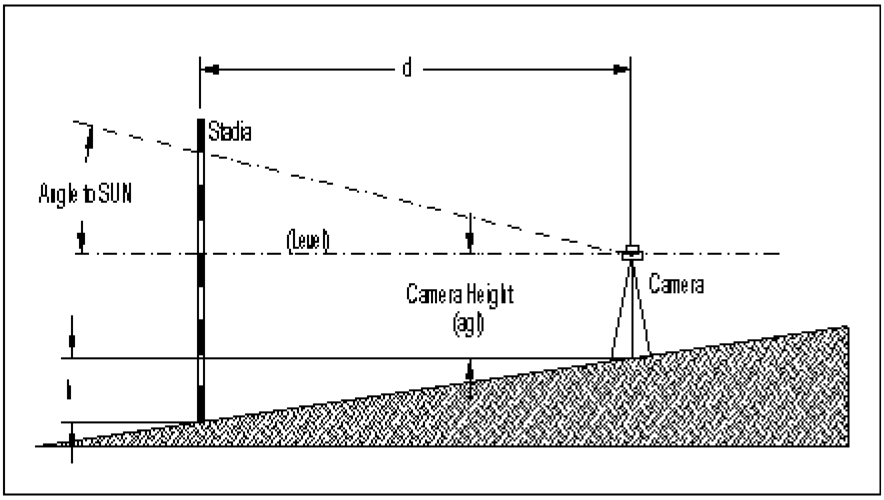

Figure 8. Vertical Scaling

In figure 8, if the vertical angle to the SUN was 10 degrees and the horizontal distance (d) between the camera and stadia was 15 metres, then from our tan rule we find that the distance up the stadia from the camera level to view a vertical angle of 10 degrees would be 2.64 metres. If the camera level passed through the stadia at say, 2.00 metres, then we would need to look 2.64 metres above 2.00 metres on the stadia, to identify the correct 10 degree angle to the SUN, which of course would be at an indicated level of 4.64 metres on the stadia.

CONCLUSION

This paper has dealt with the process of identifying and visually demonstrating the SUN's position in the sky for a particular time, date and location on the earth's surface. Through a controlled process of accident site surveying and photography, it is possible to thoroughly investigate such an issue and visually represent your results on a series of collision site photographs.

Such information may well be crucial evidence in those matters where the sun (or moon) position is an issue, the result of which will speak for itself and either prove or disprove any such an allegation.

Further to this, the very nature of such evidence requires thoughtful and careful investigation, the result of which openly exhibits and reflects a high standard of professionalism that can only be viewed with interest and respect by juries and legal authorities.

ACKNOWLEDGEMENTS

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REFERENCES

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