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Determining the Time and Day of Photography

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ABSTRACT: Photographs taken by crime victims and perpetrators are at times important evidence. Their time of photography may also affect their value as such. Three methods of determining when a picture was taken by using the content of the picture are presented. The methods utilize solar direction—measured from shadows in the photograph, identifying flowering wild plants and correlating cloudiness with meteorological observations. Solar direction is the most accurate and involved method and therefore is the main part of this paper. A case using all three methods is described.

KEYWORDS: forensic science, photography, date, shadow, clouds, flowering, plant

Photographs submitted to court as evidence have the deficiency inherent in many documents of being difficult to date. When the pictures were photographed or submitted by parties with an interest in declaring an incorrect time of photography, the need to verify this time may arise. In this paper we present three methods for dating pictures by using their content. These methods are applicable only in some pictures, because the indicators appear only in a fraction of evidence photographs. It is helpful to obtain as many different pictures as possible from the same negative in order to increase the probability of getting indicators.

Case

In a neighbor building dispute case submitted to court, the plaintiff complained that the defendant was starting to build on his roof without the neighbor's permission. On 11 Nov. 1996 the court handed down a verdict to cease and desist. The plaintiff claimed that the building continued after the verdict. Five months later, on 10 April 1997, the defendant declared in court that the present situation was the same as that at the time of the verdict and as proof submitted photographs of the building which he claimed were taken at the time of the verdict. The local Police Investigations Office suspected forgery and submitted the photographs to the DIFS to determine if they were taken at the time claimed in court.

Out of 20 of the defendant's photographs taken during the day, one (Fig. 1) had a patch of sunlight on the floor coming from a southeastern window. Seven of the photographs had sky with clouds in them. In two photographs shrubs with yellow flowers were visible (Fig. 2).

Theory

Solar Direction

The axis of the earth's rotation is tilted by about 23.5 deg. The effect of this tilt changes during the year with the earth's orbit around the sun. Due to this the sun's position in the sky is a function of the location, the time of the day and the day of the year. Since the location is usually known, two unknowns remain. These unknowns can be found by solving equations for the solar position (azimuth and elevation). Approximate functions are given in the Appendix. Each position corresponds to two days in the year. One of the two days obtained using this method must be eliminated by other means. The accuracy of the results of the solar direction method lies in the precision of the estimation of the sun's position, the day and, to a certain extent, the location. There are two main steps for obtaining the time and date:

1. Measurements for determining the sun's position at the time of photography
2. Calculations

Following is a summary of the tasks entailed in these steps, basic functions are given in the Appendix.

1. Measurements

While making the measurements, it is important to estimate errors and uncertainties for all values. This is to obtain the full range of possible days. Errors can add up to significant values and at certain times (around the solstices), even a small error can have a strong influence on the accuracy of the final result.

(a) Identifying and marking the place of the shadow end appearing in the photograph, in reality.
(b) Identifying the end of the object creating the shadow end and marking the direction that it makes with the shadow end on the floor or ground.
(c) Measuring the horizontal and vertical distance between the points identified in a and b.
(d) Repeating the steps a–c for the current solar position, instead of that appearing in the photograph, while recording the exact time and marking the shadow direction on the floor. This step is required for accurate orientation of the floor, it

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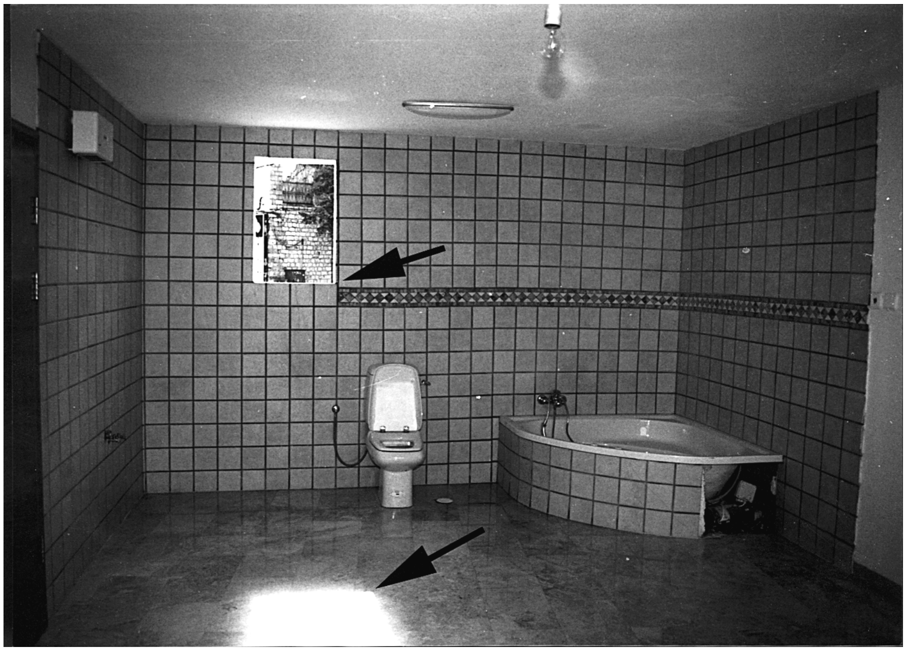

FIG. 1—*Photograph of window and patch of sunlight on floor (right corners of window and floor are marked by arrows).*

FIG. 2—*Photograph of flowering wild plants.*

does not necessarily have to made with the object creating the shadow end in the photograph. Using a magnetic compass in domestic areas is usually not accurate enough for orientation.

(e) Measuring the azimuth angle between the current shadow direction and the photograph shadow direction determined in b.

2. Calculations

(a) Calculating the solar azimuth for the current solar position.
(b) Calculating the solar azimuth and elevation for photograph solar position.
(c) Finding the two days of the year and time of day corresponding to the solar azimuth and elevation.

Flowering Wild Plants

All the questioned photographs are searched for noncultivated plants. Many species of cultivated plants have varieties covering a broad flowering or fruition season and therefore are not definitive. Samples of the plant are removed from the place where they appear in the photograph. The samples should include flowers, fruit, or seeds if present, and the plant's height should be recorded. The samples are identified by a botanist. If the plant samples will not be identified within a day or two, they must be preserved by pressing in paper a short time after picking to prevent wilting and mildew formation.

Once the plants are identified, their flowering season is determined by referencing a plant guide. Due to annual and local flowering fluctuations, a more accurate determination of the flowering season may be obtained if current field reports in the vicinity exist for the particular species. Obviously the photograph must have been taken during the period corresponding to the plant's status in the picture.

Clouds

This method does not give a definite time of photography but can be useful to rule out a claimed time of photography. A meteorological observatory or Air Force base in the vicinity is required since their records will be needed for comparison with the photographs. The sky appearing in the questioned photographs is searched for clouds. It is important to try to identify the character of the cloudiness (partiality, height and type). The records for clouds on the questioned date are compared with those appearing in the photographs.

Experimental

Measurements (Figs. 3 and 4)

We identified and marked the location of the right corner of sunlight patch in Fig. 1 on the floor using its relative position in the floor tile pattern. This was done by using the random pattern in the floor tiles. The corner of the window creating the right corner of the patch was located and marked. The marks were made on paper adhesive labels applied to the floor, these were used throughout the procedure and removed after photographing at the end. A perpendicular was lowered from the window corner and its intersection with the floor was marked. From this point a perpendicular to the wall was drawn all the way to the patch corner mark. A final perpendicular was drawn from the patch mark to the wall perpendicular and their meeting point marked.

The following measurements were made:

1. From the window corner to the floor—1420 mm.
2. Perpendicular from the patch corner mark to the wall perpendicular—65 mm.
3. Marked meeting point of the last two perpendiculars to the wall—1885 mm.

The floor and wall leveling were checked and found to be normal.

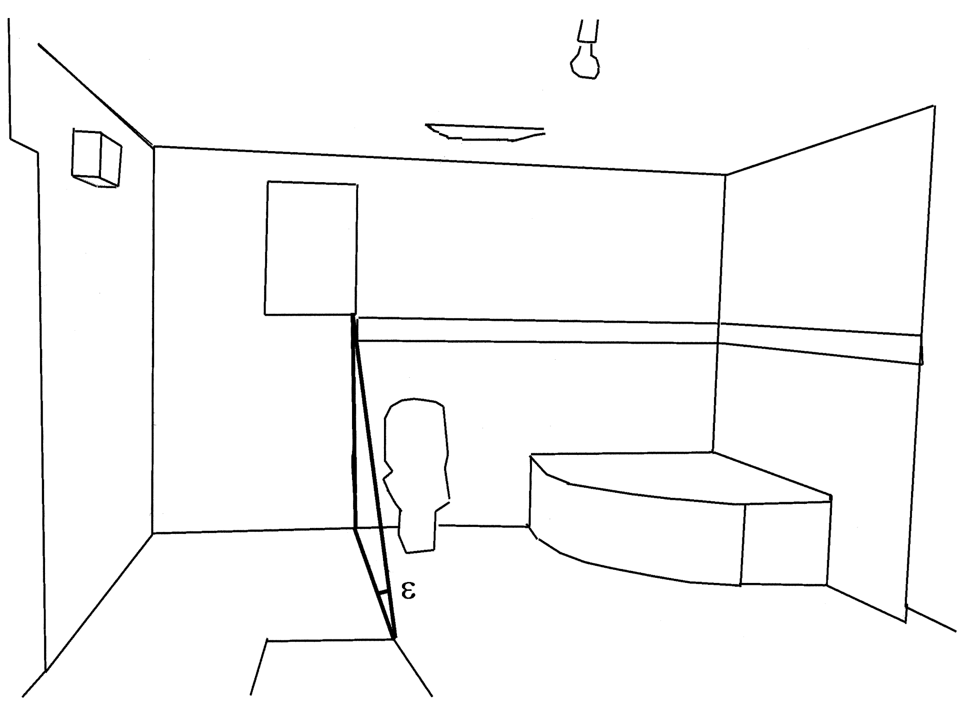

FIG. 3—*Solar elevation measurement.*

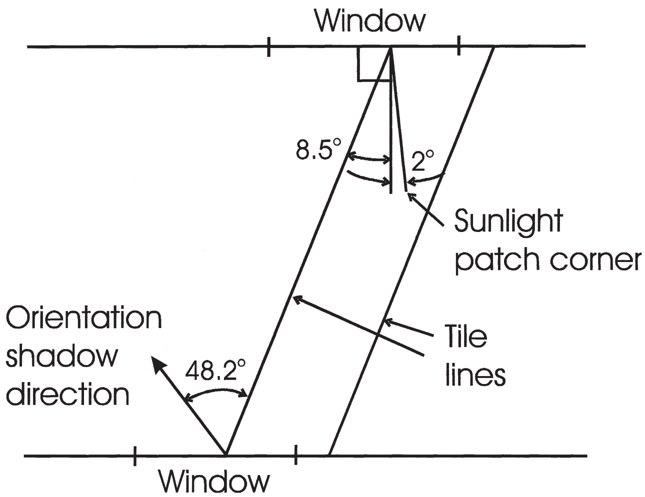

FIG. 4—*Azimuth configuration.*

For orientation of the floor we used a window on the opposite side of the room, since the sun was not shining through the relevant window at the time of the measurements. The floor tile created straight lines running across the room, so it was easy to transfer angles measured from one window to the other. A perpendicular to the floor was constructed, using two drafting triangles. The exact time was recorded and the base of the perpendicular and the edge of its shadow were marked on the floor. The angle between tile line and the wall perpendicular was measured at 8.5 deg.

The angle of the shadow with the line of the floor tiles was 48.2 deg and the time was 14:34 Israel Daylight Saving Time, 24 July 1997. The angle between the tile line and the opposite wall was found to be 81.5 deg. The coordinates of the location were 35.3 deg E longitude and 32.8 deg N latitude.

Calculations

The following calculations were made using the formulas in the Appendix. The solar elevation ε (see Fig. 3) was found using

$$\varepsilon = \tan^{-1}(1420/1885) = 37.00°$$

The azimuth relative to the wall perpendicular is:

$$\zeta_0 = \tan^{-1}(65/1885) = 1.97°$$

Using the empirical formulas we find the declination at the time of the orientation measurement is 19.80 deg and the equation of time is 6.49 min. Using formulas 2–4 of the Appendix we find the azimuth of the sun during the orientation measurement to be 68.44 deg from South (248.44 deg from North). Using basic geometry rules we can now calculate the azimuth:

$$\text{Orientation azimuth} + \text{Relative azimuth} = \text{azimuth (see Fig. 3)}$$

$$(68.44° + 48.2°) - (8.5° + 1.97°) = 106.2°$$

The result is rounded to the nearest 0.1 deg.

With formula 4 we obtain a declination of 8.6 deg. This corresponds to 11 April and 31 August. Formulas 5 and 6 give us a time of 8:16 Standard time.

TABLE 1—*Indicators in evidence photography*

Indicator	Cases
Shadow indicating solar direction	27
Flowering wild plants	26
Clouds	13
None	47

Results and Discussion

Sun

In our case there was no dispute that the pictures were taken after October 1996 and before the middle of April 1997, so we determined that the pictures were taken in the beginning of April 1997. Due to measuring errors and uncertainty, the day of photography was determined to the accuracy of ±5 days and the time to ±10 min.

The scientific work in the following two categories was performed by external experts outside of our division.

Plants

Plant samples were taken from the places where they appeared in the photographs. Some had dried in-situ and it was not necessary to preserve them. The plant samples were submitted to a botanist with the request that he state whether they could have flowered at the claimed time.

The plant samples were identified as *Hyoscyamos Aureus.* Field observations for this species gave the earliest time of flowering as three months after the claimed time of photography.

Clouds

Photographs with clouds were submitted to the Israel Meteorological Service with the claimed time of photography and the assumed range of correct time.

The Meteorological Service found low and medium height clouds in the submitted photographs. According to observation records in the vicinity, on the claimed day of photography the sky was covered with high clouds. On this basis they determined that it was unlikely that the submitted photographs were taken on the day claimed.

Conclusions

Methods from a number of disciplines were found to determine the time and day that pictures were taken within useful accuracy in a specific case. While demanding much effort, this method could prove invaluable where pictures are submitted for proof of alibi in serious crimes.

We conducted a study to estimate the relevance of these methods. A sample of 100 cases in our casework where evidence photography was utilized was searched for the existence of indicators. The results of this study appear in Table 1.

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Appendix

Formulas for Solar Calculations (1)

Nomenclature

α	Right ascension
ε	Solar elevation angle
δ	Solar declination
λ	Latitude
τ	Hour angle (0 at Noon)
ζ	Azimuth
ζ_r	Relative azimuth
ζ_o	Orientation azimuth
ω	Longitude (Degrees) East is positive
g	Mean anomaly
L	Mean longitude of sun
φ	Ecliptic longitude
o	Obliquity of ecliptic
n	Number of days from Noon UT (formerly Greenwich Time) January 1, 2000 (Epoch J2000.0).
N	Time zone
t	Time (hours)
Δx	Distance between shadow source and shadow end (horizontal)
Δy	Distance between shadow source and shadow end (vertical)
E	Equation of time (hours)

1. The solar elevation is calculated from the measurements using the following formula:

$$\varepsilon = \tan^{-1} (\Delta y/\Delta x) \tag{1}$$

2. The orientation azimuth is found by calculating the direction of the sun measured in 1 day using the three following formulas (1).

$$\varepsilon = \sin^{-1} (\sin \delta \sin \lambda + \cos \delta \cos \lambda \cos \tau) \tag{2}$$

$$\tau = \left(12 - t + E + N - \frac{\omega}{15}\right) \frac{\pi}{12} \tag{3}$$

$$\zeta_o = \sin^{-1} \left[\frac{\cos \delta \sin \tau}{\cos \varepsilon}\right] \tag{4}$$

3. The azimuth is found by correcting the relative azimuth with the orientation azimuth (adding or subtracting depending on the geometry).

4. The day of the year may be found using the following formula (1), which gives the declination δ and an almanac having tabulated values for the declination. An empirical formula for δ follows shortly.

$$\delta = \sin^{-1} (\sin \varepsilon \cdot \sin \lambda + \cos \varepsilon \cdot \cos \lambda \cdot \cos \zeta) \tag{5}$$

The following formulas give the time. The equation of time may be found in a current issue of an almanac (2), or the empirical formulas given here may be used.

$$\tau = \sin^{-1} \left[\frac{\cos \varepsilon \cdot \sin \zeta}{\cos \delta}\right] \tag{6}$$

$$t = 12 - \frac{12\tau}{\pi} + E + N - \frac{\omega}{15} \tag{7}$$

Empirical Formulas for Calculation of Declination and Equation of Time (2)

The following formulas give the declination with a precision of 0.01 deg and the equation of time with a precision of 0.1 min for the period of 1950 to 2050. The factors used here are from the 1984 edition. [n = number of days from Noon UT (formerly Greenwich Time) January 1, 2000 (Epoch J2000.0).]

For 1998 the following formula may be used [$n = -731.5 +$ number of day in year + fraction of day from Midnight UT]:

$$L = 280.528° + 0.9856474° \, n \tag{8}$$

$$\varphi = L + 1.915° \sin g + 0.020° \sin 2g \tag{9}$$

$$o = 23.439 - 0.0000004° \, n \tag{10}$$

$$\alpha = \tan^{-1} (\cos o \tan \varphi) \tag{11}$$

α is in the same quadrant as φ.

$$\delta = \sin^{-1} (\sin o \sin \varphi) \tag{12}$$

$$E = \frac{12}{\pi} (L - \alpha) \tag{13}$$

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