*Continuous Strip Photography—An Approach to Traffic Studies**

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PART 2

ABSTRACT: *Measurements of traffic factors such as speed, volume, and orientation are accomplished with sufficient accuracy and economy to warrant widespread utilization of the technique. The difficulties encountered in the application of continuous stereo strip to the usual topographic photogrammetric problems do not apply.*

The type of measurements made and the photographic subject-matter of existing roadways, combine to eliminate the need for controlled spatial orientation. Discussion indicates how roll, pitch, and relative azimuth are taken into account.

Data extraction and reduction is greatly simplified relative to that in the usual photographic solution to traffic problems. The possibility of automatic and computer systems is also discussed.

EDITOR'S NOTE: This paper is PART 2 of the paper by Wohl and Sickle which was presented as a part of the Panel on Special Applications of Photogrammetry. Part 1 is on pages 397–403 of the June 1959 issue (XXV, 3). In some mysterious way the manuscript for Part 2 was separated from the manuscript and illustrations for Part 1. This is much regretted. The incompleteness was only recently discovered. Parts 1 and 2 were prepared by the two authors in collaboration and were intended as a joint presentation. Mr. Wohl contributed most of Part 1 and Mr. Sickle most of Part 2.

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INTRODUCTION

THE practicability of photogrammetric traffic measurements involves consideration of the accuracy required and the total geometry of the situation.

The first portion of this paper (Part 1)* indicates the accuracy requirements for traffic studies. The traffic engineer, unlike the surveyor, deals with statistical problems involving hundreds or thousands of vehicles out of many thousand. He does not have the problem of absolute accuracy for each point in a terrain model. Thus a velocity accuracy requirement of 5 per cent or, at lower speeds 10 per cent, is all that is necessary.

The various factors involved in making the continuous stereoscopic strip, photographic flights and the resultant measurements can be analyzed independently. The discussion developed here treats these things practically and is not burdened with exhaustive theoretical proof. Two classes of factors affect this problem. The first is data collection or factors relating to the photographic flight, and most attention is devoted to these. The second group concerns making measurements from the film and data reduction.

DATA COLLECTION

Before proceeding with an analysis of the individual problems usually considered in photogrammetry, it is well to get a clear picture of the basic situation. By their nature,

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traffic studies are performed on existing roads, highways and streets. With continuous stereo strip, the photographic flights are normally made at altitudes of 1,000 feet and less. Given the strong visual aid of an existing roadway and the low altitude, the pilot can, to a very considerable degree, keep himself centered and use visual clues to maintain proper orientation.

A typical project involves periodic flights over one or more study sections of a highway network. Future developments in traffic engineering may lead to studies of ten mile, twenty mile, and longer sections of a route; but today the flight lines are usually less than five miles long.

SCALE

Scale is one of the first questions that arises in a discussion of continuous stereo strip photography. In this case, however, scale is not a factor. It is not necessary to know the scale to make vehicle velocity and many geometric measurements from continuous strip photography. The following discussion is presented to indicate how scale could be handled if and where necessary.

The first and most obvious method is to accept the existence of scale variation and to utilize the roadway and adjacent culture to reconstruct the scale from the film. This applies to scale across the line of flight, and is so easy to do that it can be done as often as is desirable.

Scale in the direction of flight is often a difficult question with continuous strip photography. However, the traffic engineer usually concerns himself with a series of roadway sections of less than 1,000 feet length. Within this narrow range, four to ten inches on the film, and considering the advanced state of the synchronization equipment, there is no problem in using the cross film scale or average of several cross film scales.

The mathematical analysis presented in the first part of this paper pre-supposes accurate film speed synchronization. Although this probably would be satisfactory, it is an unnecessary assumption. The X parallax of a fixed object in the two halves of the film (D in Figure 4) is the image of the air base.*

This figure (R) measured in inches multiplied by the scale factor (X) in feet per inch gives the apparent air base. The same approach can be used throughout to make all vehicle speed measurements, without reference to the actual air base, film synchronization, or scale.

* Figure 4, herein given, is a repeat of the illustration on page 402 of the June issue.

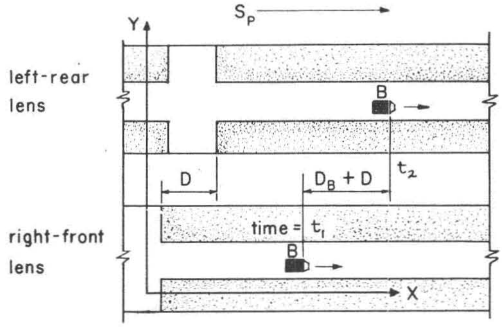

FIG. 4.

Proceeding with this analysis, formula I is really

$$D = RX \qquad (1a),$$

and formula 3 for vehicle speed becomes

$$S_B = S_p \left(\frac{R_B}{R + R_b} \right) \qquad (3a).$$

At this point scale and its related variable, altitude, drop out of the speed and volume determinations. Thus, the existence of scale variation and difficulties in measuring scale along the line of flight do not affect traffic velocity measurements made from continuous stereo strip photography.

RELATIVE AZIMUTH

The first section of this paper mentions measuring the speed of vehicles whose motion is at an angle or is perpendicular to the direction of film travel. Actually there have been no instances of this, and due to the simplicity of lining up for flights, their chance of occurring is slight. (Some studies however, will require the measurement of cross traffic.)

Whether it arises by design or by accident, however, the problem is easily solved. For angles of less than five degrees the correction is insignificant. Beyond this point two courses are available; measure distances in the direction of vehicle travel directly, or measure along the X axis (direction of film travel), and multiply by the secant of the angle between the two directions of travel.

ROLL TILT

Variation about the roll axis is an important consideration for most photogrammetric work. This is not the case, however, when using continuous strip photography for traffic work. In the first place the strip camera is gyrostablized about the roll axis. Thus the amount of roll possible in the interval between recording vehicle in the two lenses, or even in a whole flight line, is limited by the very slow drift rate of the gyro.

For individual vehicle measurements, the time interval involved does not exceed 2.25 seconds for vehicles traveling in the same direction as the aircraft, and is less for vehicles opposing the direction of flight. With larger scale, smaller parallax angles, or different vehicle speeds the time is less. An average figure would approximate 0.7 to 1.1 seconds.

Since there is no true vertical reference it is possible to have the degree of "permanent" roll during a flight. In practice it is felt that this will never exceed five degrees. Within the limit no distortion of the traffic information is caused.

It should be noted that even if tilt about the roll axis were a factor, the accuracy of speed measurements of vehicles traveling parallel to the line of flight, or film motion, would be unaffected. The image of the air base, *R*, would be proportionally different for each lane of pavement, but so would the image of vehicle motion. Thus measurements made along these lines parallel to the axis of tilt could be made with the same accuracy as in the non-roll situation. As mentioned before, scale across the line of hight, perpendicular to the axis of tilt, does not enter into the calculations of vehicle speeds and volumes.

PITCH TILT

Like roll, tilt about the pitch axis can be discounted as a source of error. Pitch, although of much greater magnitude than roll, has a different effect upon continuous stereo strip photography. Due to the automatic scanning and film speed control system, motion about the pitch axis causes the film to speed up or to slow down depending upon the direction of rotation. On the film this is recorded as a lengthening or shortening of the image of the air base. The image of vehicle motion is changed accordingly so that the resultant measurements compensate for the distortion.

It is possible for the aircraft to maintain a relatively constant nose up or nose down attitude. Although this condition produces a scale difference in the two halves of the film, it is interesting to note that none of the studies or measurements contemplated so far require working with scale on both halves of the film. Thus a constant nose-up or nose-down attitude poses no more difficulty than level flight.

The preceding discussion of scale, relative direction of aircraft and vehicle travel, roll, and pitch has shown that these factors do not handicap the computation of vehicle speeds and volumes from continuous stereo strip photography. The foregoing is written in reference to the nature of the problem and not as a theoretical photogrammetric proof. Full weight is given the types of measurements to be made, the range of speeds anticipated, and most importantly the particular characteristics of continuous strip photography.

GROUND SPEED

Aircraft ground speed does not fall into the same category as the other factors discussed. The accuracy of vehicle speed, volume and time spacing measurements depends upon the accuracy of the ground speed determination. At the low operational altitudes required for continuous strip, traffic study projects, navigational solutions for ground speed are too unreliable.

However, the answer lies in this low altitude and in the large number of distinct landmarks which exist along a roadway. With a viewfinder and stop-watch, the photographer gathers the necessary information for computing the average ground speed for every flight line or for every two to four miles. These short distances represent times of less than two minutes, and speed varies only a small per cent from the average.

Recording errors are possible, and these must be considered. In a recent test of twenty-four runs, twelve in each direction, over a single three-mile course, the data indicate excellent reliability, probably better than two per cent.

Data Reduction

Continuous stereo strip photography has one very important advantage so far as data reduction is concerned. This has been mentioned in the first part of this paper, but it bears emphasis. The continuous strip photograph captures all vehicles, and their time separated images are irrevocably tied together in proper orientation on one piece of film.

No new data reduction equipment has been designed for the strip photography traffic problem, so present techniques lack the efficiency and accuracy which will ultimately be obtainable. Even with present system set-up time is less than three hours per roll, 60 to 100 test miles, and vehicle speed measurements can be taken at the rate of 20 to 30 per hour. With minor modifications, 30 to 45 measurements per hour will be the expected rate on the next project.

In traffic work, recording and computation are separate from making the measurements. The data can be handled by hand or put directly on cards or tape for automatic computation. The amount of data recorded varies greatly with test design, and recording and calculating procedures are altered accordingly.

With present techniques the operator measures to the nearest thousandth of an inch. Reproducibility of measurements is on the order of 96 to 98 per cent. This is well within the accuracy requirements that have been established.

Substantial improvements in both efficiency and reliability can be obtained easily with present technology. Essentially an elongated coordinatograph with optical fixtures is all that is needed. Suitably engineered, the readout rate would exceed 90 vehicles per hour with better than 99 per cent reliability.

It is possible to conceive of a monitored automatic electro-optical readout and data conversion system which at the least would more than double the data reduction output and efficiency. In other words it appears possible to develop full utilization of computer techniques. When this occurs continuous stereo strip photography will be the analog source that the traffic engineer will use for creating complete mathematical models of traffic flow and behavior.

Summary

This paper discusses most of the salient points regarding the utilization of continuous stereo strip photography for making traffic measurements involving vehicle speed, volumes, density and spacing. In addition, the usefulness of strip photography for studying many of the factors related to traffic geometry is implied.

Derivation of formulae is not complete, but is sufficient to indicate the nature of the measurements which must be made from the film. Essentially these are image of the airbase and image of vehicle motion.

Secondly, the paper discusses the various factors which might affect the accuracy of various traffic measurements. These are presented individually and are related to the basic accuracy requirements for traffic work. Roll, altitude, and so forth are not deleterious to the traffic measurements, but care is required in the calculation of aircraft ground speed.

Data reduction and processing are considered briefly to illustrate basic feasibility. The fact that stereo-strip photography contains both of the time-displaced images on one film offers tremendous advantages. Ultimately photogrammetrists may be able to handle these data automatically and to provide traffic engineers with the tool he needs to perform mathematical analysis of traffic flow problems.

The end result will be increased safety and more efficient flows with less wear and tear on drivers. This is a goal citizen drivers and traffic engineers as a profession fervently hope is achieved, as the number and density of vehicles using our highway system multiplies each year.

*Aircraft Position Location by Single Photograph Technique**

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GENERAL

During the summer of 1958 the Royal Canadian Navy carried out evaluation tests on the Decca Navigation system with a view to adapting this instrument to the peculiar needs of the R.C.N. in the Maritime area. The constant position indicator system, using a roller map and stylus, was installed in a number of aircraft including a fixed wing type and a helicopter. The problem of exact

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