Traffic Data Acquisition from Aerial Photographs By Photographic Image Processing

T. A. BAGGOT, Data Systems Division, International Business Machines Corporation, Kingston, New York

•THE APPROACH to traffic data acquisition known as image processing employs electrooptical scanning and conventional electronic data processing techniques to extract useful data from imagery. Basically, image processing involves three steps:

1. Digitizing—visual images are converted into digital images;
2. Transforming—digital images are converted into useful data; and
3. Processing—the useful data are used to achieve the desired output for a particular task.

Digitizing is the conversion of visual images into number patterns that can be automatically interpreted by digital computers. This conversion is accomplished by accurately directing a light beam to a tiny increment, as small as 0.001 in. in diameter, of a photographic negative or positive.

The quantity of light energy either transmitted or reflected by each increment is measured by a photoelectric cell and translated into a number. A basic scanning system is illustrated in Figure 1. The components of this scanning system are a light source, an optical arrangement, a phototube, a phototube amplifier, and an analog-to-digital converter. This system must automatically convert an area on the photograph

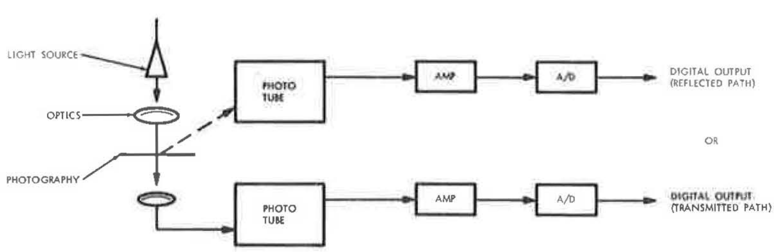

Figure 1. Basic scanning system.

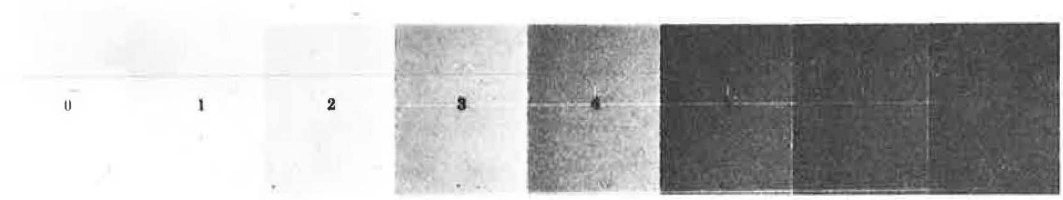

Figure 2. Typical gray scale.

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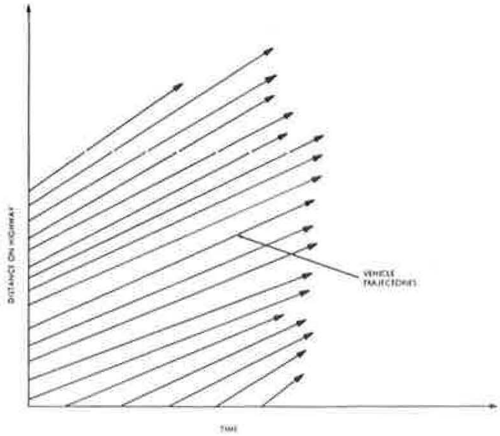

Figure 3. Space-time diagram.

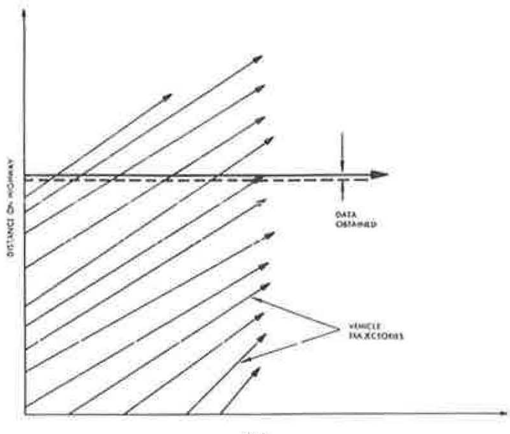

Figure 4. Space-time diagram for conventional traffic detector.

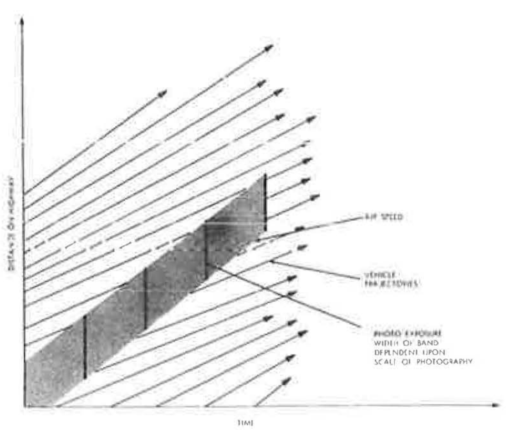

Figure 5. Space-time diagram for aerial photography.

into digital data and conveniently store the data so that it will be readily available for processing in a computer.

The number obtained by measuring the light energy corresponds to a predetermined scale and is called a gray scale. For example, a shadow cast by a vehicle might be given the value 7, whereas a 0 might represent a white line on a highway. Thus, digitizing an image gives a pattern of numbers that indicates the varying shades of gray in that image. Figure 2 illustrates a typical gray scale. It should be noted that this scale has only eight shades and serves only as an example. The number of levels established in a gray scale depends on the density range of the image and on the number of gray shades required for a particular application.

The result of digitizing imagery is a pattern of numbers, stored on magnetic tape, which corresponds to the varying shades of gray in the scanned image. A digitized image contains thousands of numbers per square inch, and, in using a spot size of one mil, the figure attained is 1 million per sq in.

TRAFFIC DATA

At this point, we should consider the traffic engineer and the information he requires. Figure 3, a space-time diagram, shows the total data available with respect to measurable parameters. Each trajectory indicates a vehicle traveling along a highway at a constant speed. From this graph we can obtain density, volume, and average velocity.

Figure 4 is a similar space-time diagram with the relationship of a conventional traffic detector added. The conventional traffic detector samples a short distance of the road for a long period of time. Measurements of speed and volume are recorded so that density can be estimated. Of particular interest is the small section of highway that is sampled. The solid and dashed horizontal lines illustrate the width of the sample strip, determined by the sensor spacing.

Figure 5 illustrates the traffic data obtainable from aerial photography on the space-time diagram. The density is readily available from a single photograph, and velocities can be calculated by tracking a vehicle from photograph to photograph. The extent of the area covered is deter-

mined by the scale of photography; a $\frac{1}{2}$-mi stretch of highway is secured by a photographic scale of 300 ft to 1 in.

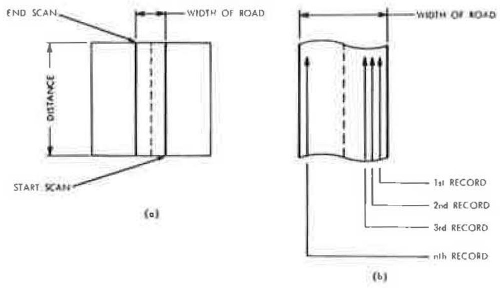

Figure 6. Scanning format.

All the space diagrams used have been for a single lane and for constant velocities. They do not show lane changes or acceleration and deceleration of vehicles. A conventional detector will not normally detect these occurrences. However, these data will exist in the photographs.

TRAFFIC DATA AND IMAGE PROCESSING

In bringing the areas of traffic data and image processing together, we first establish a scanning format for traffic data acquisition (Fig. 6a). Starting at the

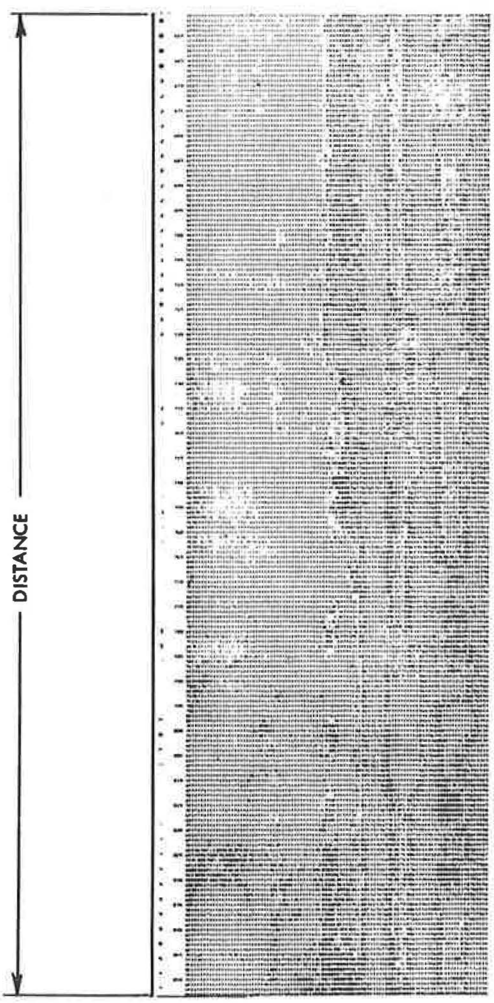

Figure 7. Printout of scanned data.

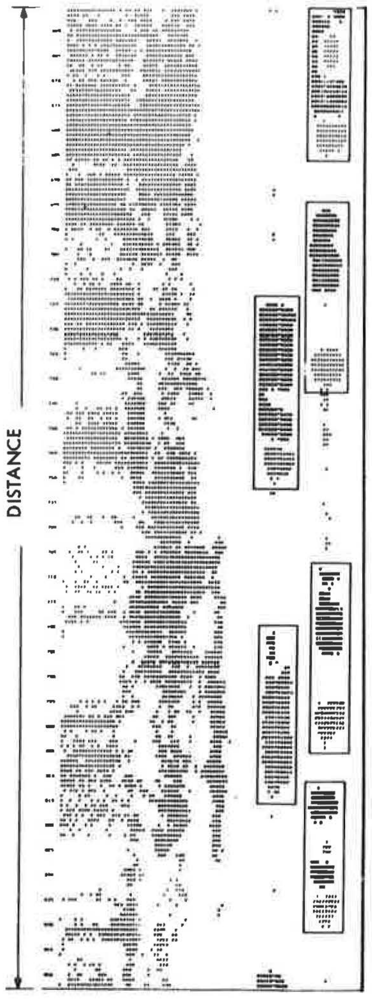

Figure 8. Printout of only extremes of scanned data (black and white).

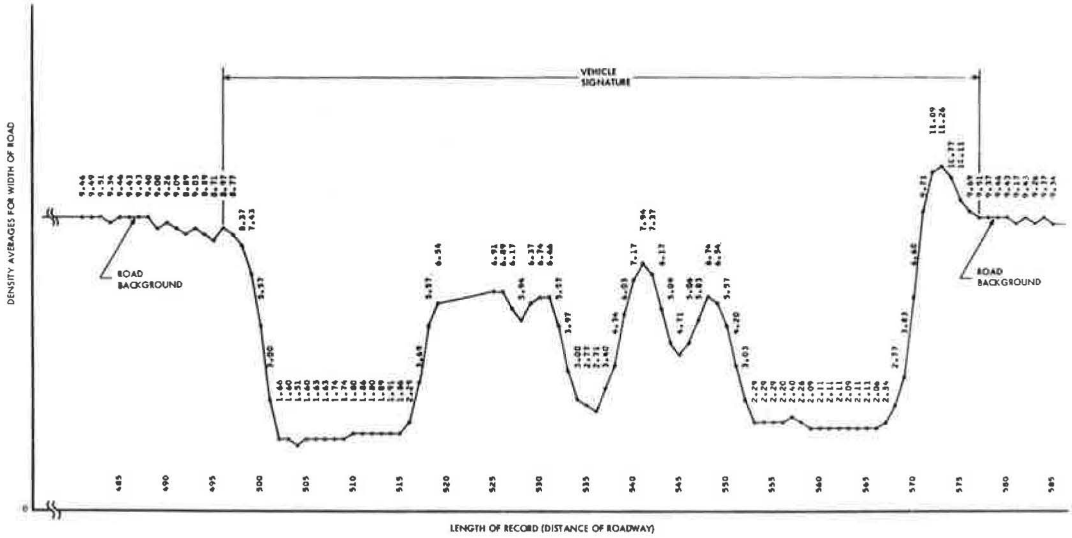

Figure 9. Output of averaging program.

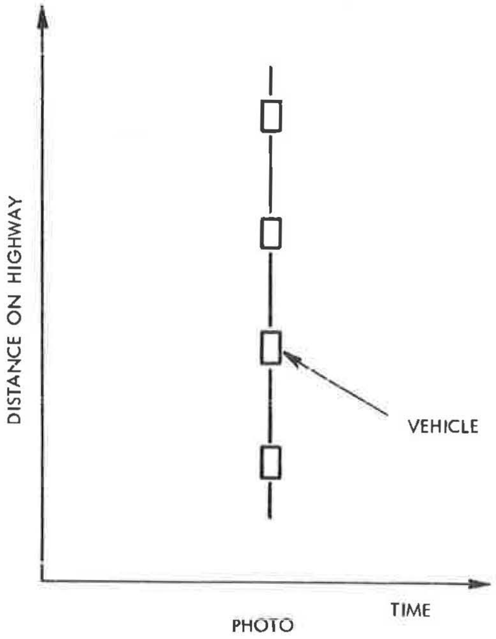

Figure 10. Data from single photograph.

lower right-hand corner of the photographed highway, we scan down the road for the desired distance. The last part of the highway to be digitized will be the upper left-hand corner.

Figure 6b illustrates the scanning and recording of the information. Each record is essentially a light profile of a portion of the highway. In computer language, such profiles are referred to as "data records." To clarify this process further, the figure shows an enlarged section of the roadway and the position of records as they are transferred to magnetic tape. A roadway represented on the photograph by an area 0.1 in. wide and 9.0 in. long and scanned with a 1-mil spot would be described by 100 records, each record containing 9,000 characters. The scanner used is capable of a 1-mil spot and of quantizing the light into 16 levels of gray. Each tape character represents the quantized gray level of a 1-mil spot on the photograph. Therefore, position across the roadway is located by record number, and position down the roadway is located by character position in a record. Computing distances on the roadway involves using the photographic scale factor. As an illustration, for a photographic scale factor of 1 in. = 300 ft, 1,000 characters of data are equivalent to 300 ft on the ground.

Figure 7 shows the data obtained in our first attempt to secure vehicular data from scanned aerial photographs. Patterns of zero's and F's can be seen in the right-hand portion of the illustration. To facilitate seeing the vehicle, we suppressed all digits except 0 and F. The result was Figure 8. Although the vehicles are outlined, it is ap-

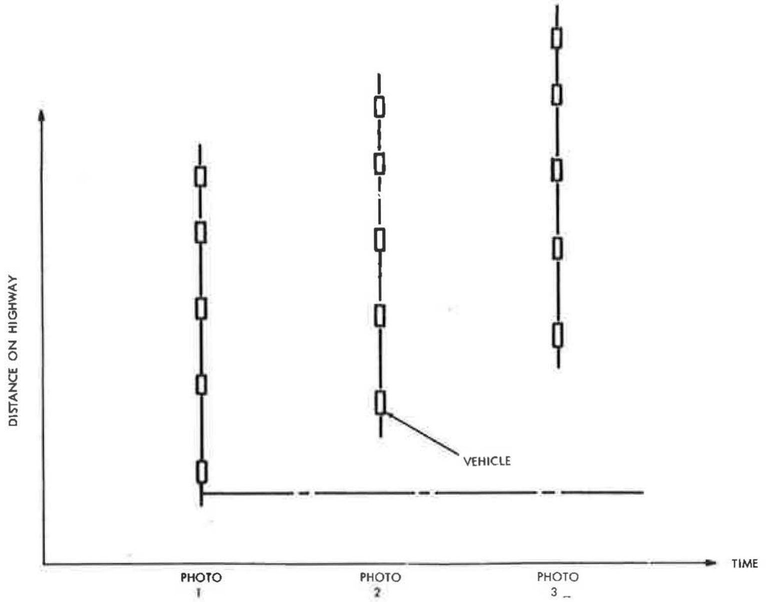

Figure 11. Data from a series of photographs.

OUTPUT OF DATA PROJECT - MODEL MARK II, VERSION 01

PHOTO TAPE NUMBER 1726				TAPE NUMBER 1721, LANE 3			
DIST	*	LGTH	IMAGE DE	DIST	*	LGTH	IMAGE DESCRIPTION
56.8	1	20.1	DAAAARG	46.5		19.5	DCEEEE
94.0	2	17.2	DAADAQ	86.5		19.5	CAABANJ
124.4	3	17.8	CAAEAQ	124.4	1	19.1	DAAAAPG
151.1	4	20.1	CAACDIL	161.7	2	21.4	CAACAMJ
209.2	5	20.1	BAFJCCG	194.7	3	17.5	CBBEDJ
257.7	6	18.8	BCFFFGB	236.6	4	19.5	DBCECIF
316.1	7	17.5	CAAEBO	304.3	5	16.5	GGDADGBBG
422.4	8	18.8	CCFFFFB	366.3	6	19.1	CDEEFFB
470.2	9	29.7	CBDFFFF	459.7	7	17.5	DAAFCM
552.1	10	17.5	EAEJCFB	508.9	8	13.5	DDFFD
645.5	11	20.1	IAAADAQ	560.7	9	18.8	CDFFFFB
740.5	12	32.3	BAABAEI	624.7		17.8	BDEFFE
841.8	13	17.8	DAAFAN	723.0	10	17.5	BBGFBG
926.6	14	19.5	EAAAAKL	844.8	11	19.8	GBBCCEJ
1023.6	15	19.8	BBGFBI	942.1	12	20.1	EAACCFN
1103.5	16	17.8	BBGFBI	1018.7		15.5	DABELC
				1075.8	13	17.2	DABGCJ
				1167.9	14	18.8	FBBCBKD
				1253.7	15	16.8	CAFICCF
PHOTO 1				PHOTO 2			

* Correlation of Vehicles, not a printout.

Figure 12. Output of two vehicle detection programs.

parent that they would stand out by themselves. The data were obtained by scanning a photograph taken with a 12-in. focal length camera at an altitude of 7, 200 ft, yielding a scale of 1 in. = 600 ft and a field of view of 5, 400 by 5, 400 ft on the 9- by 9-in. photograph.

The coding used on the printout for the 16 shades of gray ranges from 0 to 9 and from A to F, with 0 corresponding to the lightest shade and F corresponding to the darkest.

For the photograph under discussion, 65 veh were counted manually from 1, 800 ft of 3 lanes of a 6-lane highway. From the suppressed printout data, a total of 62 patterns of 0's and F's was recognized. The vehicles not identified in the scanned printout included two in the shadow of an overpass and one in the shadow of a tree.

With this initial success of detecting 95 percent of the vehicles present, our next effort was to write a program to detect the existence of a vehicle on the roadway. This program calculates the average gray level across the lane for the scanned distance of roadway. For example, if the width of the lane is equivalent to 35 records or individual gray-level characters, the average of these characters is computed and stored. This process continues for each 1-mil increment along the roadway until the density averages for the entire length of scanned lane have been assembled. The results of this program present average gray levels for the distance of roadway under observation. Figure 9 shows the output of the program.

The establishment of these averages provides the criteria for detecting the presence of deviation in the road background. A vehicle-detection program operating on these data would yield vehicle location and density data. A deviation from the road background falling within minimum and maximum criteria determines that a vehicle exists at this point. The deviation, as shown in Figure 9, is called the vehicle signature. At this point, we have three factors necessary for obtaining traffic data from aerial photographs:

1. We have detected the vehicle;
2. We have determined the vehicle's location; and
3. We have the time at which the photograph was taken.

These data are shown graphically in Figure 10.

This information by itself is almost meaningless. However, we can continue repeating the procedure described previously and obtain data for a series of individual photographs. These plotted data are illustrated in Figure 11.

The space-time diagram is becoming crowded with individual data points, which by themselves are of minor significance. Our next step in this research was to track a vehicle from one photograph to another. The key to this problem was the vehicle's signature, mentioned previously. The signature is first coded; then, by correlating, we are able to locate a vehicle in the next successive digitized photograph. The technical feasibility of this procedure was verified by our last experiment, completed in July 1964.

The aerial photographs which were digitized contained 42 veh common to both photographs. The results were as follows:

1. Forty vehicles correlated;
2. Two vehicles did not correlate, because they passed under a tree; and
3. There were no false correlations.

Figure 12 is a sample of the vehicle detection program with the coded signature. The output displayed in this figure describes the location and the length of the vehicle and includes the image description. This is the coded vehicle signature. The vehicles listed in the output of photograph 1 were correlated to those in photograph 2. The time between photographs was 5 sec. The first two vehicles shown in photograph 2 are new to the scanned area. The vehicles in photograph 2 between 9 and 10 and between 12 and 13 moved from lane 2 to lane 3. This correlation, using the allowable variances in individual characters and the tolerances on overall descriptions, was performed by hand.

RECOMMENDATIONS

What information does the traffic engineer need? Speed, density, headway? These and other meaningful engineering outputs can be derived. With proper programming, the desired traffic characteristics or parameters can be obtained by extending the aforementioned techniques.

What has to be done to make this an operational system? Nothing; it is operational now. However, the term operational should be qualified; the system is operational only as an experimental tool. The drum scanner which has been used to investigate this application is essentially a laboratory device and not production equipment. For production work, the scanner would be inefficient and restrictive.

Further research is required on both the equipment and the programming. In the area of equipment, a scanning bed similar to an input-output XY plotter should be developed to control the scanning of curved highways and interchanges. The scanning head should be a variable-width line scanning device which would scan the photographs once for each lane. The programs now in use must be optimized and organized into a programming package. Additional programs must be written for obtaining the specific data required by the traffic engineer.

Automatic traffic data acquisition from aerial photographs by photographic image processing has been proved technically feasible. Further research and development are required, however, for an economical operating system.

ACKNOWLEDGMENTS

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