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Image Motion Nomograph

Shutter speed and resolution can be analyzed quickly for nearly any aerial photographic situation.

INTRODUCTION

THE PROBLEM OF IMAGE MOTION and its effect on resolution has been dealt with by many authors to various degrees of refinement, and for various or for *any* conditions of object and camera movement. Solutions for the latter obviously become very involved. Simpler situations, e.g., in vertical photography for mapping purposes, (i.e., without image motion compensation) can still occur over a wide range of the significant parameters,—viz scale, focal length, lens-film resolution, required resolved distances or resolved angles, linear and angular velocities of the camera with respect to the object, and the available times of exposure—all of which may be expressed in various units. It therefore seems desirable to display the relationships among these parameters, in any probable units, and so simplify the numerical evaluation of the required answers in the *required* units. The present graph has been designed for this purpose.

CAUSES OF IMAGE MOTION

Two basic causes of image motion exist:

1. Transverse *linear* movement of the camera with respect to the object.
2. *Angular* movement of the camera with respect to the object.

Image motion due to the first is a function of scale, and to the second, of focal length. Needless to say, combinations of these usually occur, but conditions will determine the *predominant* cause, which will govern the appropriate time of exposure.

CONSTRUCTION OF THE GRAPH

The graph is constructed to perform multiplication or division (in a variety of units) and is based on three assumptions:

1. If n is the number of *lines* per mm resolved by a given lens-film combination, $1/(2n)$ is the width of the smallest resolved image (in mm), i.e., the mean width of a light and dark *bar*, (because a *line* is measured from center to center of like bars and therefore includes one of each).

2. Therefore, the smallest resolved distance D on the ground is $(2n \times \text{scale})^{-1}$ mm, and the smallest resolved angle A at the lens is $(2n \times f)^{-1}$ radians.

3. The degradation of resolution due to image motion is related to the image motion and the statically resolved image, as defined by Trott (1960), as follows:

Image Motion	*Per Cent Loss in Resolution*
Width of smallest resolved *Line* $= 1/n$ mm	30%
1/2 width of a *Line* i.e. 1 *Bar* $= 1/2n$ mm	11%
1/4 width of a *Line* i.e. 1/2 *Bar* $= 1/(4n)$ mm	4%

Therefore, if the time of exposure is made no greater than the time required for the image to move the width of one *Bar*, the loss in resolution will be negligible—11 per cent.

CALCULATION OF APPROPRIATE TIME OF EXPOSURE

The appropriate time of exposure can be found (given sufficient data) in each case as follows (Figure 1):

1. CONSIDERING TRANSVERSE LINEAR MOVEMENT OF THE CAMERA

A Y-line through the "scale number" S (or scale^{-1}, e.g., 20,000) intersects a NW diagonal through the "Resolution R_1," (e.g. 25 lines/mm = 50 bars/mm, and 1 bar = 20μ), and an X-line through this intersection to the *right*, indicates the resolved distance D on the ground ($20{,}000 \times 20\mu = 400$ mm or 0.4 metres). A Y-line through the linear velocity LV of the camera (e.g. 50 metres per sec) intersects the X-line through D just found, and a NE diagonal from this intersection indicates the

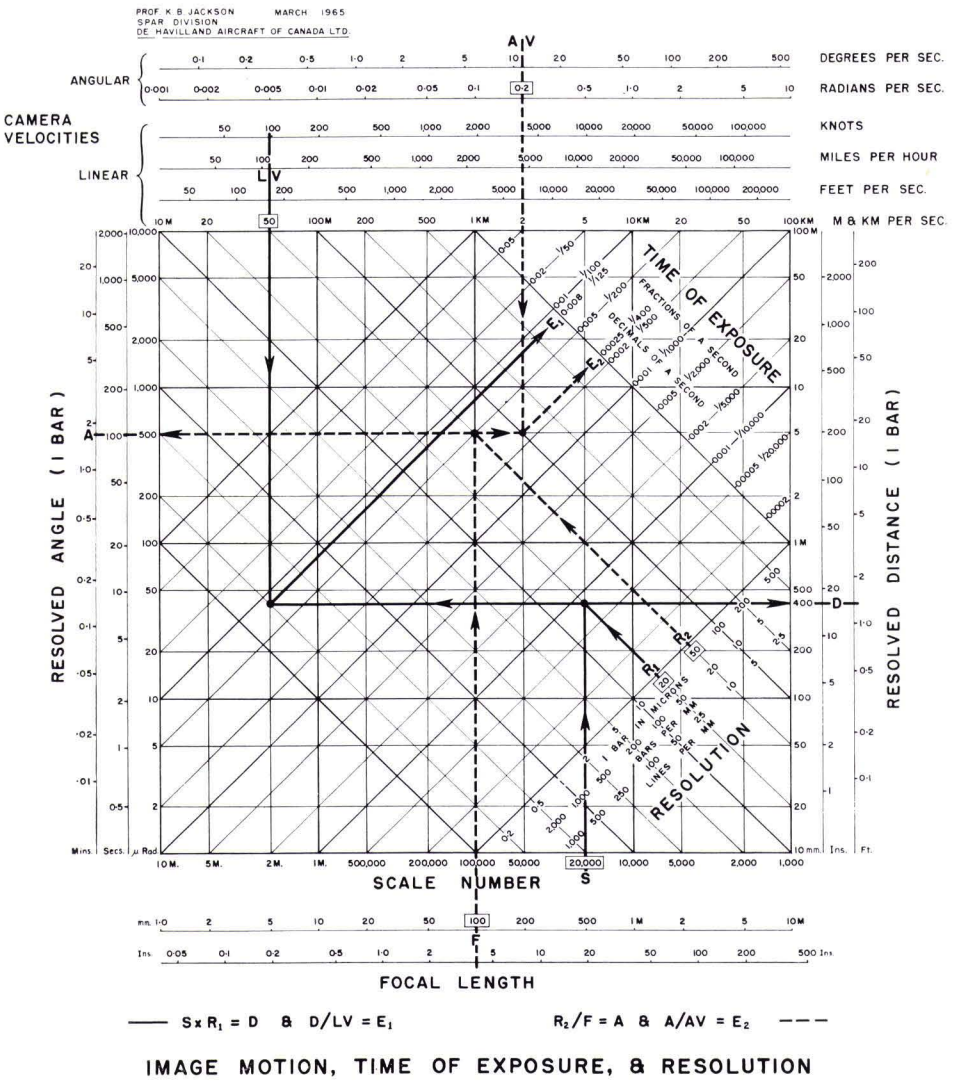

IMAGE MOTION, TIME OF EXPOSURE, & RESOLUTION

FIG. 1. Sample calculations relating linear and angular velocities of the camera, lens-film resolution, time of exposure and resolved distances and angles.

time E_1 required to travel that distance at that rate (0.4 metres/50 m per sec. = 1/125 sec.), which is the appropriate time of exposure.

2. CONSIDERING ANGULAR MOVEMENT OF THE CAMERA

A Y-line through the focal length F of the lens (e.g. 100 mm) intersects a NW diagonal through the Resolution R_2, (e.g. 10 lines/mm = 20 bars/mm, and 1 bar = 50μ), and an X-line through this intersection to the *left* indicates the resolved angle A at the lens (50μ/100 mm = 500μ radians). A Y-line through the Angular Velocity AV of the camera (e.g. 0.2 radians per sec.) intersects the X-line through the resolved angle A just found, and a NE diagonal from this intersection indicates the time E_2 required to rotate through that angle at that rate (500μ radians/0.2 radians per sec = 1/400 sec.) which is the appropriate time of exposure.

OTHER CALCULATIONS

The solution of other problems will become obvious: The relative sizes of objects and images. Actual image motion in given conditions. Permissible camera velocities, or maxi-

mum times of exposure to restrict image motion to prescribed amounts, etc., in any probable units.

MEASUREMENT OF ANGULAR VELOCITY OF THE CAMERA

A means of measuring and recording the angular velocities of the camera, particularly during the time of exposure, and generally during the operation of the camera in flight, is urgently needed to complete the analysis of image motion with current cameras and mounts, and with improvements *that should be developed.*

FORUM

Gentlemen:

I am enclosing your invoice for my annual dues for 1966 along with my additional check in the amount of $15 to pay the increased charge.

I have supported the Society because of my background and experience in photogrammetry in hopes of receiving some direct benefits applicable to my particular field. Month after month the journal has contained papers of interest to the highly technical photogrammetrist but has, I believe, failed to consider many of us who are trying to justify its use in the mining engineering, geological, geophysical or geochemical areas. Several of us have discussed this matter and feel that the Society should at least consider the possibility that this group (which incidentally never seems to be represented through the Operating Committee or the Executive Organization of the Society) should have some technical data directed its way occasionally. I appreciate that we may be much in the minority; however, with this dues increase, one must take a hard look at the justification for support.

As a consistent user of results from photogrammetry, I would appreciate your consideration of applications to the mining industry and/or its exploration programs.

Very truly yours,
(*A Member*)

Dear Member:

The problem of obtaining down-to-earth articles on the methodology and applications of photogrammetry has been discussed by many of us repeatedly without arriving at a satisfactory solution. Those of us who have been in contact with the regional organizations of the Society are very much aware of the situation.

The difficulties stem from the fairly simple fact that very few of these papers are submitted for publication although essentially all of those submitted are accepted. On the other hand, we receive many highly technical papers which deserve consideration for publication from the standpoint that they represent profound advances in the art of photogrammetry. These technical papers are frequently the result of costly research.

However, the officers of the Society are very much aware that the bulk of the membership is engaged in daily operations which might perhaps seem to be less glamorous than, say, lunar mapping. These members receive the journal as essentially their only contact with the Society, and the journal becomes the only return for their membership fees.

You perhaps may have some helpful suggestions as to how the Society can get out of this dilemma. The Society is not in the financial position of paying for articles, but your ideas on this would be interesting. The annual prizes for the best articles usually go to those who are backed by extensive facilities for research and editorial assistance which may be discouraging to the independent author. How do you think this can be remedied?

How can the Society encourage the independent authors to submit practical articles? The articles need not be long nor highly technical, and the fact that they may not be written in the best style can ordinarily be cared for during the Society's normal editorial processes.

Your suggestions are earnestly solicited. The very life of your Society may be at stake! Thanks for writing.

The Editor.

CARTOONS

We are indebted to "Dutch" Kelly, surveyor of Bethesda, Maryland, and to Wendell Taylor, Cartographer, Coast & Geodetic Survey, for a group of sketches on the lighter side. The drawings will be employed from time to time as the opportunity presents itself. If you also have original doodles that you would like to contribute to such foolishness, mail them to the Editor.