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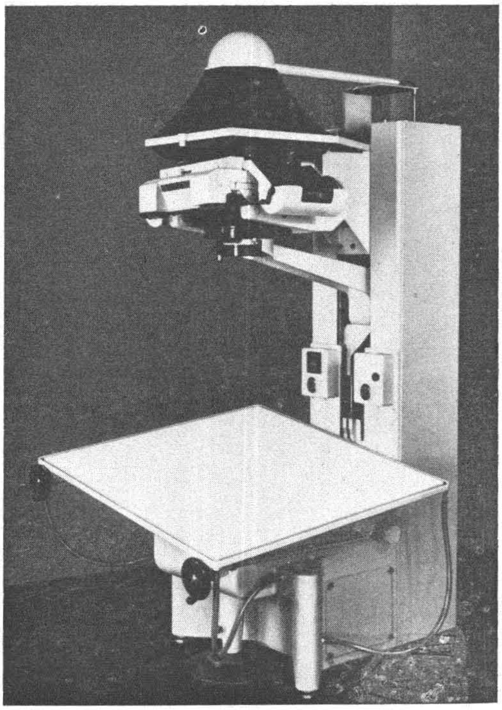
A Photogrammetrist's View of Automation

Contrary to some trends in automation, numerous photogrammetric operations are performed better, more easily, and more economically by human hands and human intelligence.

(*Abstract is on page 263*)



The SEG V (Zeiss Aerotophograph GmbH Munich, 1963) constitutes a step in the evolution and automation of photogrammetric rectifiers.

Introduction

The term "automation" is now so widely used and generally accepted that hardly anybody bothers to define it in all its implications. However, the term is not quite as clear as we may imagine at first glance. There is at least *one* competitive term, viz. "mechanization." Let us, first of all, define the difference between these two terms.

Prof. Dolezalek (Stuttgart) has given the following definition in the journal *Automation:* "Automation means to relieve man of the execution of ever-recurring, uniform, spiritual and manual operations and to sever his temporal links with the rhythm of the technical equipment." This idealistic view could be called "true automation." It is fully applicable to a technically and economically well-balanced world.

In addition, however, there is also a type of automation which is "false" in the sense of the aforementioned definition, viz. the one which is born out of a temporary necessity and which is designed only to cover up technical or economic shortcomings, and in particular the shortage of qualified personnel. This "false" automation should rather be called "mechanization." True automation is, of course, mostly connected with a mechanization in the literal sense of the word or adapted to electrical or electronic elements.

Under this aspect, a true automation was initiated in the field of photogrammetry long before the term "automation" had become a world-wide slogan. In 1911, von Orel entitled one of his publications: "The Stereoautograph as a means for the automatic processing of comparator data." If we consider the process of contouring on the basis of point measurements in the comparator, and if we compare this procedure with the simple tracing of a continuous contour line in the Stereoautograph, there can be no doubt about the fact that this is automation in the best sense of the word. The present status and success of photogrammetry are certainly due to a large extent to this early trend towards automation, which even today is characteristic of this field.

These general remarks appear necessary in order that the following primarily technical outlines may be correctly understood. We are living in an age in which in technology practically "anything is possible." This is not only an advantage but also a great responsibility for our time, because it is not at all certain that anything which may be possible technically will also be correct and turn into a blessing to mankind.

The Aerial Camera

The following remarks are restricted to aerial photogrammety. And even of this field we shall examine only the more essential working phases, without, however, underestimating the importance of intermediate processes.

A photogrammetric system is a chain which is as strong as its weakest link, and what has once been lost in an intermediate process can never be regained.

The basis of any photogrammetric work is the photograph. Ever since the early days of photogrammetry, much thought has therefore been given to the production of a photogram of optimum quality. In photogrammetry, the term "good photography" does not only imply good photographic quality, but also the required overlap with the following photo and with adjacent flight strips. And this is where the above definition of automation—viz. that the operator " . . . must be relieved of ever-recurring manual operations . . . "—is particularly applicable. Only then will he be free to concentrate on the special requirements of the particular flying mission and thus to obtain an optimum result.

The first aerial survey cameras built during World War I by A. Brock in the United States or by Oskar Messter in Germany (Figure 1) had already made allowance for this consideration. Even in the early days of photogrammetry, the photographic equipment was automated to an extent which reached the limits of existing possibilities.

Even today, one of the basic problems of aerial photography is to obtain a clean overlap of at least 50%. If this percentage of overlap should not be reached in one single pair of photos, an otherwise perfect flight strip of several hundred miles may be entirely worthless. In general, this process is nowadays controlled with ground-glass or telescopic viewfinders, with the operator only having to synchronize a chain of splines, a spiral line or a similar device with the motion of the ground image. Chicago Aerial Industries have proved that the operator may even be relieved of this adjustment. Their automatic intervalometer has all the characteristics of true automation. Whether such far-reaching automation is necessary for civilian air photography is another question which will not be discussed in this paper.

In this "Precision Automatic Intervalometer," a combination of lens, grid, condenser and photocell is used twice (Figure 2). Both these units are so arranged that under parallel incident light, identical ground points will in one unit lie imaged on the photocell, and in the other unit on the grid. Bright ground points will thus produce an alternating current through the photocells, whose wavelength is proportional to the flight height and the air speed. The discriminator connected to the scanning unit then computes and generates the tripping impulses for the camera on the basis of the corresponding focal-length and the desired amount of overlap.

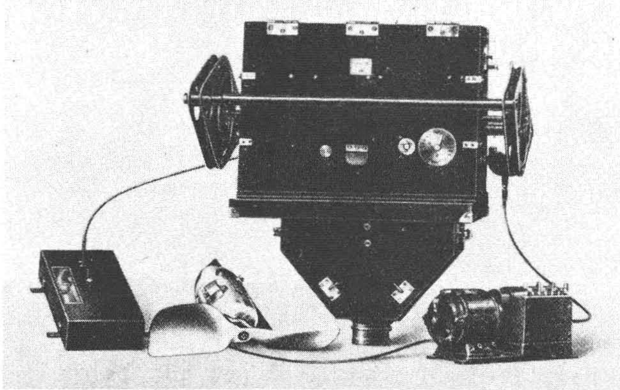


FIG. 1. "Reihenbildner II," 6 cm×24 cm, built in 1916 by Oskar Messter. Wooden camera body, electric motor drive, variable gear. The generator was driven by a propeller. Left, the intervalometer.

The "Quo vadis" flight path recorder (Figure 3) designed by Aerotopograph GmbH in 1929 shows that very early in the history of aerial photogrammetry attempts were made to solve these problems. For those days, such a far-reaching conception of automation is astounding.

It is not the purpose of this paper to discuss the automatic functions performed in the interior of the camera and the magazine—such as film advance, film flattening, shutter operation, etc. Such automatic functions are now taken for granted, although they may be quite a headache for the designer.

ABSTRACT: *Although the word itself was not employed until recently, "automation" has been a counterpart of photogrammetry for several decades, resulting in time-saving photo rectifiers and stereo plotters. The Stereomat-type of instruments comprise a further step in the evolution of plotters and the ideas apply also to the functions of the Orthophotoscope. Photo interpretation imposes a difficult task for automation. Mechanization differs from automation: a reasonable limit must exist in the automation of photogrammetric processes where the importance of the human operator cannot well be ignored.*

The ideas published by Rosenberg in this journal in 1955/56 will not be discussed either. They can undoubtedly be considered as the ideal of maximum mechanization within the photogrammetric taking and plotting technique. However, their importance is primarily restricted to the military field.

RECTIFIERS

The importance of both true and false automation becomes even more apparent in the case of the different plotting processes.

In spite of general technological progress and refined plotting techniques, the simple aerial mosaic is still extremely popular. This is probably due to the fact that its production, including the determination of ground control (for example by slotted-template triangulation) is very simple, while the result is entirely sufficient for many cases. The economy of this technique is above all determined by the rectifier which is used, and by the extent to which this rectifier is automatic. This instrument presents practically every degree of automation, starting with the simple enlarger with inclined table and ending with a completely automatic instrument full of refinements, the so-called "Automatic Mosaicker." The Frontispiece and Figures 4 through 7 depict the development and automation of rectifiers.

This paper is not intended to decide whether these ultimate developments are still reasonable. Such a decision will primarily depend on the use made of the equipment. However, it is interesting to note the manv different steps of automation that are possible in such an instrument, and how widely opinions differ as to how far such automation should go.

So, for instance, in 1926, the ATG presented a table to be tilted in two directions, which at that time meant considerable ease of operation. The SEG I (1934) already featured automatic focusing, both on and off the optical axis—in the form of the so-called Scheimpflug condition. And finally, the ease of operation of the SEG V introduced in 1953, which required only three manual settings, was topped only by the "Automatic Rectifier" and the "Automatic Mosiacker." In the latter instrument, the aerial mosaic is even assembled without human interference.

A similar development—which undoubtedly must be considered partly positive and partly negative—can be noted in the case of stereoplotters and in those instruments which occupy an intermediate position between single-photo and stereo plotting—i.e. instruments which have become known under the name of Orthophotoscope.

STEREOPLOTTERS

Let us first consider stereoplotting equipment. According to the introductory remarks, the Stereoautograph and even more all the stereoplotters which followed, were automatic devices, e.g. for plotting contour lines. However, the development of the "Stereomat" by Hobrough as well as related designs have shown that there is still much room for automation.

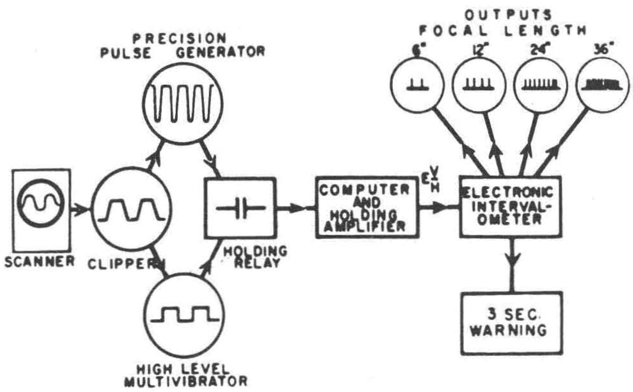


FIG. 2. Automatic Intervalometer by Chicago Aerial Industries. Left, diagram of scanner; right, block diagram of discriminator.

As is known, the Stereomat is intended to replace the human element in the orientation of aerial photographs and the plotting of contours. Figure 8 shows the basic principle of the instrument. It will be noted that it is designed on the double-projector principle, except that the plotting table is replaced by a cathode ray tube and the lamps by two photocells. The luminous spot of the cathode ray tube scans a small unit area, i.e. the spatial relationship of the points is resolved into a chronological order. The ray emitted by the tube passes through a negative where it is attenuated in accordance with the density of the image, and is then transmitted to the two photocells where it is converted into two alternating voltages (Figure 9). If the respective portions of the negatives are identical, the same will be true of the phases of the alternating voltages; x or y-parallaxes will give rise to a phase shift which can be used for height adjustment or for orientation, depending on whether x or y-parallaxes are chosen as a criterion.

Consequently, when the correction of y-parallax is coupled with the orientation elements to be operated by servo-motors, the Stereomat is capable of performing the relative orientation fully automatically. With the existing means, automation of exterior orientation is also no longer a problem. If the image is scanned in strips in x or y-direction, the corresponding cross sections can be obtained automatically. They may be used, for instance, for controlling an Orthophotoscope.

A contour map can be produced in two different ways. We may copy the work of the human operator, i.e. set a constant elevation and control the cathode ray tube—which fills the role of the plotting table—in such a manner that this condition is left unaltered. Or we may scan the image in cross-sections and mark the passing of certain contour lines in some way or other on the plan, as was repeatedly discussed in this journal.

Although the details of design of Stereomat-type instruments vary with the different manufacturers, the underlying principle is the same. Consequently, all these instruments have certain shortcomings and present certain problems which are inherent in the principle itself: Since the scanning beam must always cover a certain, though small area, it is only the mean value of this area which can be used for the elevation setting. Small details may therefore be lost. It is also obvious that heavy ground cover or vegetation may falsify the result considerably, without being apparent. If, for instance, the floating mark

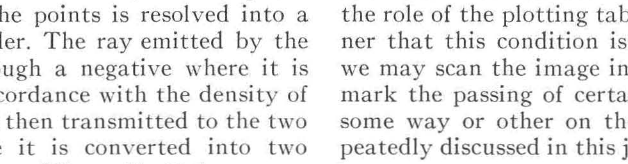


FIG. 3. "Quo vadis" flight path recorder after Hugershoff, by Aerotopograph GmbH, Dresden (1928).

enters woodland, it will follow the contours along the tree tops instead of along the ground. The human operator, on the other hand, is able to recognize this source of error and can frequently make the necessary correction.

DIGITIZATION

In the course of the last ten years, the numerical processing of single points—primarily signalized boundary points—has gained more and more ground. In this instance also, there is one operation which permits automation and which even calls for it: the recording of the hundreds or thousands of single points which have to be measured. It is now taken for granted that all the instruments employed for such measurements are equipped with an automatic recording unit. However, this was not originally the case in the past. The first instrument to be provided with a printing counter was the Zeiss Stereoplanigraph. The stereoplotters of other manufacturers followed and immediately made the next, indispensable step forward, viz. the simultaneous transfer to punched cards or punched paper tape, so that the measured values could be fed directly into the digital computer.

A third solution was presented by VEB Jenoptik who coupled their plotting instrument directly with a small computer. This "Coordimeter" can be used for the computation of orientation elements, for transformations, etc. The advantage that the instrument will thus produce the values directly in Plane State Coordinates is offset by the disadvantage that it will hardly be possible to make full use of the computer if it is directly coupled with the plotting instrument.

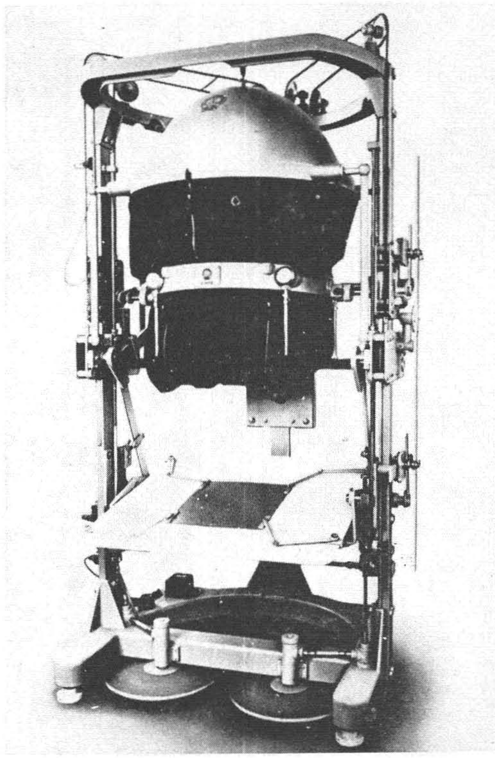


FIG. 5. SEG I rectifier (Zeiss-Aerotopograph GmbH Jena, 1934)

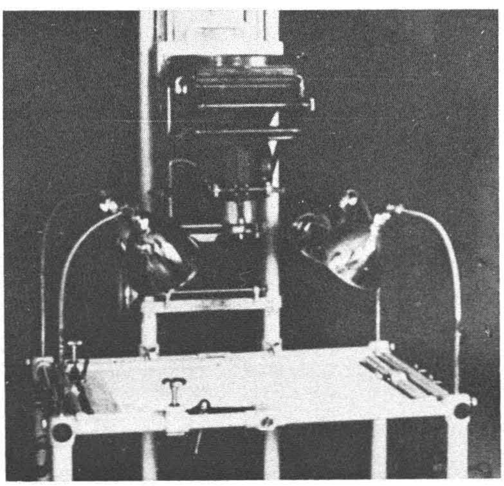


FIG. 4. ATG rectifier (Aerotopograph GmbH Dresden, 1926)

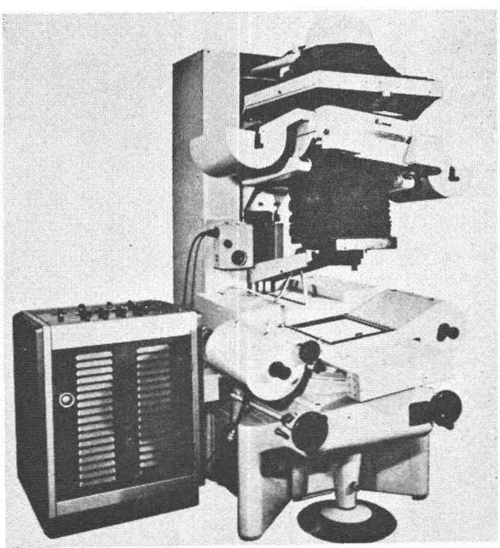


FIG. 6. Automatic Rectifier (Union Instrument Corp., Plainfield N. J., 1962)

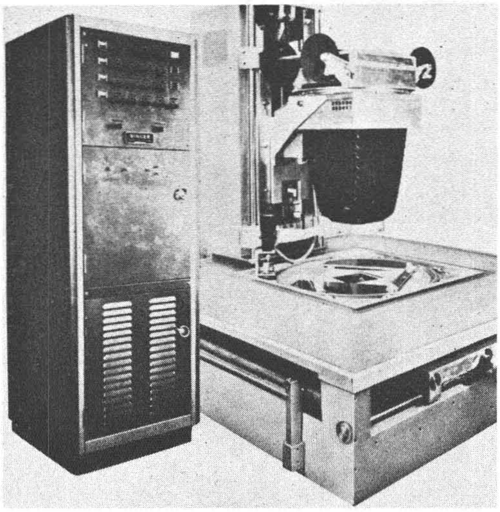


FIG. 7. Automatic Mosaicker (rectifier) (Union Instrument Corp., Plainfield, N.J., 1962)

Another process, the automation of which is highly desirable, is the setting of the large number of points to be measured in the plotter. This problem is known to be under study—any results of this work have, however, not yet come to the author's knowledge.

Another group of instruments, which follows directly from these considerations, viz. the automatic coordinatographs, will not be discussed in this paper, because they are not photogrammetric instruments in the proper sense of the term.

THE ORTHOPHOTOSCOPE

Finally, mention should be made of an instrument which in the opinion of the author will demonstrate the value and the uselessness of automation in a particularly striking manner. This is the Orthophotoscope and similar instruments.

The instrument has repeatedly been discussed in this journal, so that only brief mention of its design will be made here. It is a special table for projector-type instruments, such as the Kelsh Plotter or the Balplex. This table is adjustable in height and carries a magazine holding light-sensitive material. The upper side of the magazine features a compound-slide system serving as a support for a slit diaphragm. This slit is about 1 to $2\frac{1}{2}$ cm. wide. While the diaphragm is moved in a strip-like pattern across the picture area, a continuous exposure is made on the photographic emulsion. The operator observes and corrects the elevation setting in the usual manner, the upper side of the slit diaphragm serving as projection surface, and the entire Orthophotoscope table being lifted or lowered. Due to the central perspective, this produces an automatic correction of horizontal position. A filter in the slit diaphragm suppresses the image from one projector on the emulsion. The result obtained with the Orthophotoscope is an orthoscopic mosaic of undistorted planimetry, which takes far less time to produce than a plot in a stereoplotter. A similar

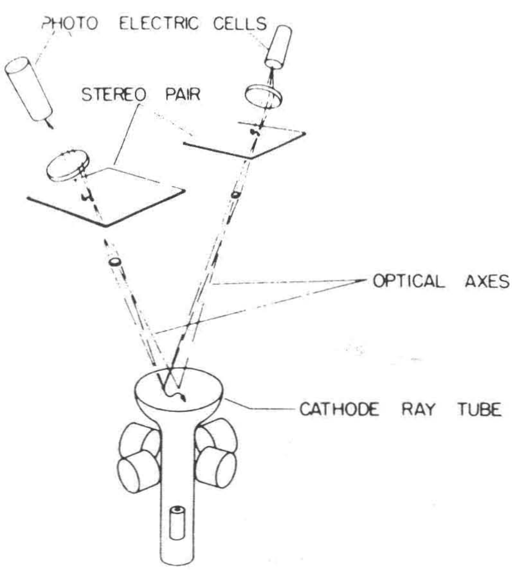


FIG. 8. Stereomat principle.

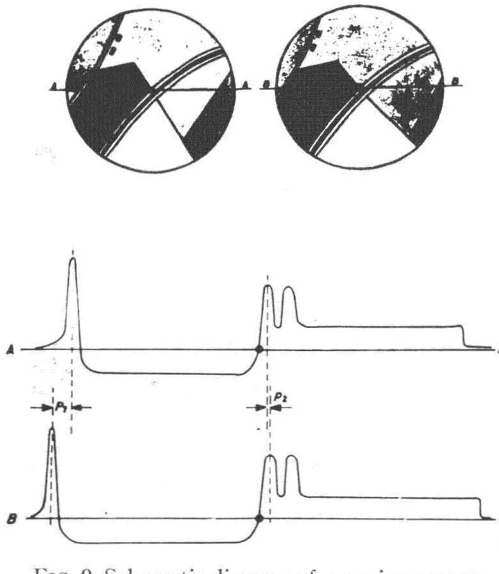


FIG. 9. Schematic diagram of scanning process in Stereomat.

instrument has recently been developed by Wild/Heerbrugg in close cooperation with PSC-Toronto.

The increased horizontal-position accuracy of aerial mosaics is undoubtedly very welcome, but it is connected with a very important condition, namely the question: How are the projection heights determined? If it is necessary for a human operator to interfere in this mechanical rhythm of image projection, we will have the contrary of what was in the beginning defined as true automation. From the viewpoint of automation, this is the critical point within this process, which up to now has apparently been solved satisfactorily only by the Wild company which has coupled the projector unit directly with Aviograph B 8 and Stereomat, so that the height adjustment is made fully automatically.

The USGS, to whom we owe the development of the Orthophotoscope, is working on a second problem too, which, however, overlaps to a large extent with the process field. A report on this work entitled "Edge Isolation Technique" was published in No. 3/1962 of this journal. According to the information available to the author, the USGS considered a combination of Orthophotoscope and edge effect as particularly promising. An even further reaching combination of Orthophotoscope—Stereomat—edge effect, which is now possible, would yield an instrument system that would be capable of solving many of the most urgent problems of our time.

Maps and Surveys

In this connection, a few remarks should be added regarding the map itself. On the European Continent, a map has always and for good reason been considered as a document. It was therefore required to be of high quality, also in performance. On the other hand, however, a large amount of surveying data are now required only for a limited period of time, e.g. for the construction of a highway or dam, so that they will become entirely useless once the construction job has been completed. Such plans should not be finished with the same care as a map. On the contrary, they should be produced with a minimum of expense and—owing to the urgency with which they are mostly needed—with the widest possible use of automation.

Photo Interpretation

Another field must be mentioned here, which, however, has hardly yet been opened up to automation. It is the field of air photo-interpretation. It is still a long way until the entire interpretation can be performed automatically. However, this is not as important at present as the recognition of certain features, such as terrain types or changes. This applies not only to the military field, as may be assumed at first glance. The botanist, forester, geologist, etc. is interested in discovering topographic or other changes in extensive areas, and this is where the tiresome and time-taking work of exploring hundreds or thousands of photos begins, until finally one picture is found which actually shows such a change. This is one of the instances in which true automation can be a great help. A. E. Murray reported on such experiments and work in PHOTOGRAMMETRIC ENGINEERING XXVII 1961. The results obtained show that these problems are not easy to solve, but that their solution is not "impossible."

Another problem should be remembered in this connection, which a few years ago seemed to present insuperable obstacles and which today has, on principle, been solved: the automatic translation from one language into another. The failure of the first trials was certainly discouraging, and even today we must not expect the machine to reproduce all the subtleties of a language, but neither is the human translator immune against errors and mistakes. In the meantime, it has become possible to obtain quite useful translations by this technique. The parallels existing with the problem of photo interpretation permit us to expect useful results in this field; also, since the basic task is very similar in both cases: The problem consists in reading a graphic representation as a word or as a term, to look it up in a catalog or a store and to record it again as a word or a symbol.

Conclusions

In closing, let us once more return to the ideas of the introductory remarks. Today, we are also able in photogrammetry "to mechanize and automate anything." But on the other hand, there can be no doubt about the fact that a multitude of operations must be reserved to human hands and human intelligence; not because it would be impossible to mechanize these operations also, but—as was mentioned in the beginning—because technological progress and human progress need not necessarily be identical and may even be opposed. Today it is general knowledge that any automatic operation must be insured by human checks. However, this applies even more to an automatic or human overall system in which only human intelligence is capable of distinguishing between right and wrong (thus, for instance, there should be a sound relationship between the expense required and the results obtained). It has been one of the objectives of this paper to point out the duty of man not only to increase his technical knowledge and his ability, but also to make the right use of this knowledge.

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