(1) *Slides.*—Photographs are contact-printed on glass slides for dimensional stability.

(2) *Projector.*—Projects image on mirror behind screen which reflects image to rear of screen. This method of rear projection conserves space and enables the operator to work on screen without obstructing projection.

(3) *Screen.*—This is enameled Herculite glass especially prepared to accommodate pencil work. The screen is mounted in an aluminum frame and stand, rigidly affixed to floor.

(4) *Measuring Devices.*—Sliding vertical and horizontal rules are mounted on screen frame. A contour meter is furnished to take off all curved line measurements. Other devices can be adapted depending on the type of measurements desired.

USES

The PhotoMetric Camera is being used in American and European research centers, universities, hospitals, and industries. A significant application of the PhotoMetric Camera is in the field of men's custom tailoring. The photographic process takes about five minutes. Approximately thirty measurements are determined from the photographs to plot the customer's shape and posture.

*Photogrammetry Applied to Making Sculptured Portraits**

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THOMAS EDISON refused to sit for a portrait. He asserted that he was opposed to painted or sculptured portraits; since made without the aid of mechanisms, they could not be "really very good." A large number agree.

Man has always searched for means to make his work less laborious, and to devise tools that extend the skill of his hands. With each tool civilization was advanced. But in the Fine Arts, and especially the Art of Portrait Sculpturing, little progress has been made. The sculptor in modeling a portrait, apart from his fingers, uses only a few simple wooden or wire tools. For measuring distances between points, he has only simple calipers and simple scales and can make measurements only in a straight line. He has no means for measuring and recording the relationship between all points on the portrait. Placing one point the correct distance from another might disturb the distances of the corrected point from all other portrait points. For getting a likeness this is especially unfortunate, as a portrait is made up of a number of irregular surfaces, each one of which flows imperceptibly into the other.

The sculptor has no aids such as the precision tools the mechanic utilizes in a modern machine shop, or with the intricate devices the photographer uses in making a photograph. He must depend upon visual guesswork and trial-and-

NOTE: The U. S. Patents for the new sculpturing methods described in this paper and issued to the author of the paper are 1.546.636 and 1.594.607.

* This is one of the papers included in the Report of the Reporter for U,S,A, Commission V of the International Society of Photogrammetry.

error methods. The sculptor of today has the same difficulties as his predecessor in that he cannot get satisfactory likenesses, and cannot get his subject to "pose" often enough.

PLASTER CASTS FROM LIFE

To secure the best possible likenesses, and to obviate unpleasant and time-consuming sittings, the sculptor often makes a plaster cast of the face of the subject. This furnishes something tangible to copy from, but forces the subject to go through a dangerous and disagreeable ordeal.

Casts of faces are not absolutely correct. The eyes are closed, hair pasted down and the characteristic features which the sculptor has to study closely for a faithful rendering are somewhat flattened by the wet plaster. Casts are valueless for portraits which are not life size, and for relief portraits which have their thickness dimensions always reduced.

New Methods of Portrait Sculpturing

Fortunately, new methods of making sculptured portraits have now been developed. A much larger number can now possess sculptured portraits. These methods are based upon photography. They allow sculptured portraits to be made to any size from the smallest for jewelry, to the largest for monuments. Most important of all, these methods eliminate all tedious posing, do away with making plaster casts and guarantee better likenesses.

The sculpturing methods consist of two separate steps:

1. Recording the form of the head and neck of the subject—the making of a "Form and Expression Record"—and
2. Carving out the portrait by using this record as a guide.

Only for the first step is the presence of the subject required. As this recording takes less than a minute, sitting for a sculptured portrait is now less effort than sitting for a photograph.

THE FORM AND EXPRESSION RECORD

This record is a strip of motion picture film showing a large number of outlines of sections through the head and neck of the subject. Its purpose is to eliminate repeated sittings and to secure a perfect form contour of the head and neck. The record is made by moving a motion picture camera together with its illumination relative to the stationary subject. Camera and illumination are so designed that during their travel they not only reveal the size and shape of the subject's head and neck, but also make a photographic form record of them. The manner of doing this depends upon the kind of sculptured portrait desired. For convenience sake all sculptured portraits can be divided into two groups:

1. Sculptured portraits in "all-around"; these are free standing and can be viewed from all directions.
2. Sculptured portraits in "relief"; these are fastened to a background, or in which the relief and the background form a unit, and in which one set of dimensions—thickness—is of a smaller scale than the length and width dimensions.

Figure 1 shows a recording device for an all-around portrait. This consists of a simple motion picture camera that can be moved in a circle around the stationary subject. The camera is fastened to a light holder that carried a light source and an opaque light shield. The light source is a row of miniature automobile lamps which is fastened to the holder in an approximate semi-circle

around the subject's head. The shield is a thin metal strip located between light and subject. The lamps are so adjusted that their filaments are in the same plane as that going through the edge of the opaque shield. With this arrangment the lamps throw a sharp shadow edge of the shield against the head and neck of the subject. The schematic diagram in Figure 2 shows a top view of a recording device for an all-around sculptured portrait.

The shadow edge divides the head and neck in two parts, a dark one and the

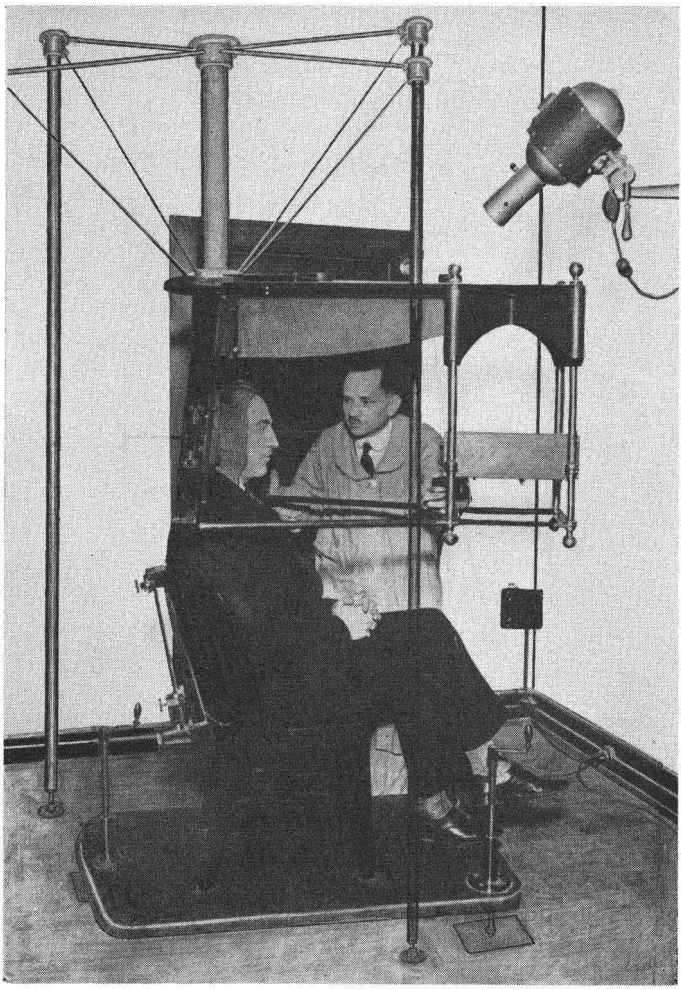

FIG. 1. Recording device for all-around portrait.

other illuminated. The dividing line follows the configuration of the head and neck, thus revealing their outlines. The revealed contour outlines are photographed by the motion picture camera.

The camera with lights and shield together form a unit. When moved through a small angle around the subject, the dividing line is also moved through a small angle, thereby revealing another contour outline of an adjacent but slightly different section through the head and neck, which the motion picture camera, actuated by the rotation of the unit, photographs. These

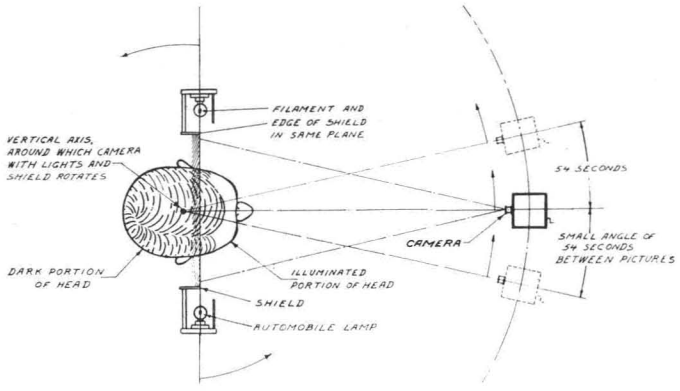

FIG. 2. Schematic top view of recording device.

sections do not go through the center of the device, but through a point about $1\frac{5}{8}''$ away from it.

A gradual movement of the camera unit around the subject reveals and records the shape and size of head and neck, section by section. For an all-around portrait the camera takes exactly 400 pictures during one complete revolution around the subject. As the camera takes 16 pictures per second, one revolution requires 25 seconds, or less than a minute. Instead of posing for hours or getting plaster casts, little effort by the subject is now required.

The combined 400 pictures represent the form and expression record. Some individual pictures, picked out at random, are given in Figure 3. Each picture is a correct outline of a section through the subject's head and neck. Combined they give the size and shape of every feature together with its correct location. The pictures give to the sculptor all information required for making the portrait without seeing the subject.

No measurements of the subject are taken when making the record. The subtle facial expressions, which generally last only for a few moments, cannot be measured by tools or memorized by the sculptor. But with the motion picture camera, its high speed lens, and its sensitive film, these expressions are easily recorded. Plaster casts from life are now entirely obsolete.

There is nothing complicated about making a photographic form

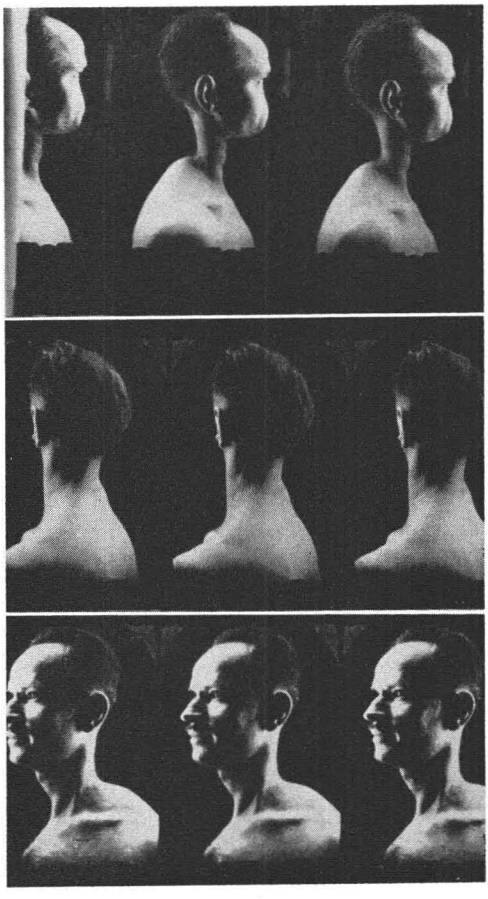

FIG. 3. Pictures from form and expression record.

and expression record. It is practically an automatic process. It requires only the starting and stopping of the traveling motion picture camera. No adjustments are required on the camera and lights for the different subjects, as the distance of the subject from the camera, the size of the stop opening, and the exposure time are always the same for all subjects. Once the camera is set, it remains set. Photographic knowledge is not needed for making the photographic records.

THE CARVING OF AN ALL-AROUND SCULPTURED PORTRAIT

Having the form and expression record, the question is how to make from the two-dimensional, flat pictures, a three-dimensioned sculptured portrait. This is easily answered. The portrait is carved out in as many different planes as contour pictures were made of the subject. Each plane has its own picture, to

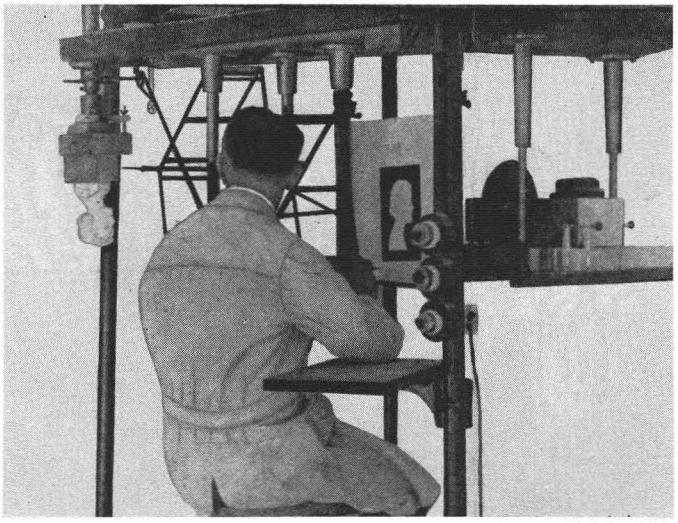

FIG. 4. Carving device for sculptured all-around portrait.

which it is mechanically connected, so that a mix-up is impossible. Figure 4 shows a carving device in operation. The photographic record is placed into a projector—a part of the carving device—and the various contour pictures of the record are projected upon a screen, one by one, as still pictures and to the size required. This size depends upon the size of the portrait wanted.

The amount to be removed from the material block for each section of the portrait is clearly indicated by its outline on the projected picture, and by the transparent area outside the picture. The connection between the projected screen picture and the material block is made by a pantograph which at its one end has a tracer point, and at the other end a revolving cutter driven by a small electric motor. The operator traces the picture outlines by following them with the tracer point of the pantograph. These movements are transferred by the pantograph to the rotating cutter, which cuts away from the block all surplus material, and leaves only an area unremoved at the cutting plane of the material block, which has the same shape as the copied contour picture used.

The entire carving process is a simple milling operation, in which the cutter is always moved in the same cutting plane for the entire portrait, and the block is moved in and out of the cutting plane, angle by angle.

A simple turn of a handwheel projects a new outline picture on the screen,

and at the same time moves a new section of the block into the cutting plane. Inaccuracies in regards to the amount the block has to be moved cannot occur, as angular movements are controlled by gearing, and straight movements by threads. This mechanical control of the block movements eliminates one set of dimensions from the carver's consideration. Measuring is entirely unnecessary. All the carver has to do is to alternate between tracing the outline of the projected picture, and turning a handwheel to get a new picture on the screen and

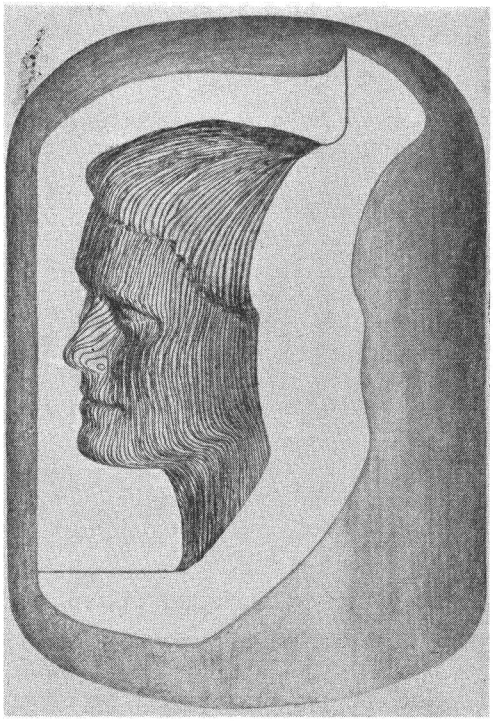

FIG. 5. Partially carved-out all-around portrait.

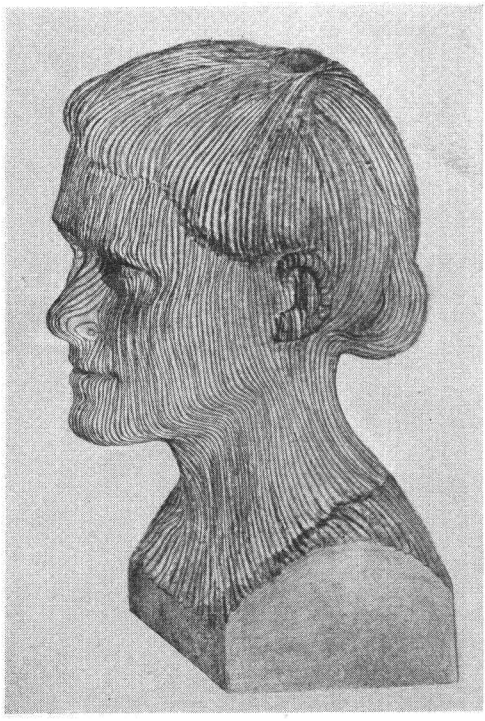

FIG. 6. Fully carved-out portrait with all surplus stock cut away.

a new section of the block into the carving position. With each new plane worked out on the block, the portrait, hidden in the block, comes more to life.

After all section pictures have been projected and used for carving out their sections, the carving process is finished. Facing the carver now is a portrait of the desired size and with all features correctly proportioned and in their true positions. It must possess an unmistakable likeness. Without seeing the subject the carver can produce a better likeness than the best sculptor can with the subject constantly before him. It is interesting to note that the portrait is carved out in an upside down position and that the carver need not look at the portrait while carving it. He only follows the picture outlines.

To obtain different portrait sizes, either the size of the projected pictures or the ratio of the pantograph has to be changed.

The material block, out of which the portrait is carved, is made of plaster of paris mixed with a large amount of water. Such plaster, when thoroughly dried, gives a solid of little weight, easily carved, possessing no grain, and with no shrink or change in shape. It must be sufficiently large in volume to contain the portrait, and to allow some stock to be removed in all directions.

Figure 5 shows a partially carved out, all-around portrait, Figure 6 a fully carved out portrait with all unnecessary stock cut away to make the portrait ready for the finishing operation, and Figure 7 a finished, all-around portrait.

THE FINISHING OF A CARVED PORTRAIT IN ALL-AROUND

The carved out portrait is covered with small steps made by the cutter in its cutting paths. The deepest corners of these steps indicate the exact position of the skin surface of the subject. The finishing consists in shaving away by hand all excessive material lying between the bottoms of the steps until they disappear and a continuous surface is obtained. The resulting surface represents the skin surface of the subject. Any small pockets or undercuts, not reached by the cutter in its travel, must be worked out by hand.

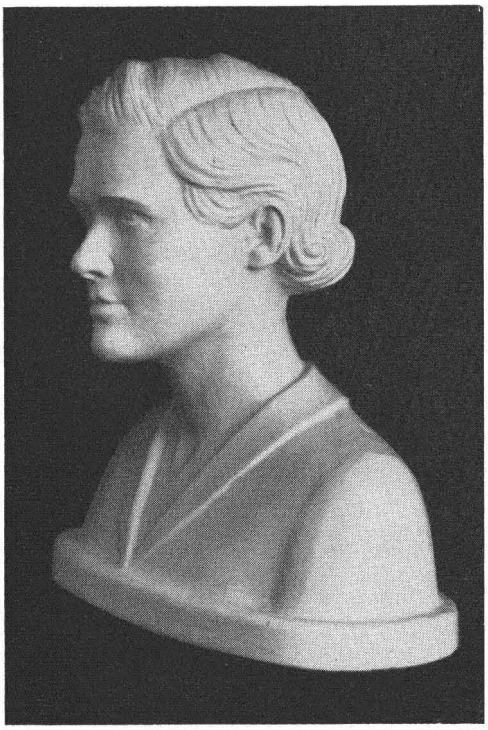

FIG. 7. A finished all-around portrait.

The various film images of the form and expression record, when projected on a screen as still pictures, help the sculptor when he wants to study minor details.

Modeling the hair in any modeling material, adding a base and shoulders —if desired—and making a plaster cast of the entire unit, finish the portrait in plaster. It can now be used as a pattern for a bronze or marble portrait.

THE SCULPTURED RELIEF PORTRAIT

What was said in regards to the new method of making all-around sculptured portraits applies equally well to the new method of making sculptured reliefs. It eliminates all tedious posing, simplifies the sculptor's work and gives better likenesses. Two steps are once more required for making a relief portrait: making a form and expression record and carving out the portrait with the help of the photographic record.

For the all-around portrait the camera with lights and shield move in a *circle around the subject*. The camera unit for the relief portrait moves in a *straight line towards or away from the subject*, and the photographed sections are parallel to each other. Only about 200 section pictures are required. With 16 pictures per second, 13 seconds are required to pose for a relief portrait.

Figure 8 shows the recording device for making a form and expression record for a relief portrait.

The camera unit is moved forward or backward by a single crank, which also operates the camera at the same time. All photographed sections are parallel to and the same distance away from each other.

THE CARVING AND FINISHING OF THE SCULPTURED RELIEF PORTRAIT

The carving is also done with a carving device which is similar to that shown in Figure 4. It has the same pantograph, the same projector and the same

screen. The only difference is that for each new contour picture the material block is moved in or out of the cutting plane of the cutter in a straight line. Different heights of the relief are obtained by changing the distances between the cutting planes of the material block. The shorter the distance, the lower the relief. Changing the distance is effected by exchanging a few gears, which control this distance automatically, and thereby eliminate the thickness dimensions. Figure 9 shows the paths the cutter made for carving a sculptured relief portrait.

The carved relief portrait is finished in the same way as an all-around por-

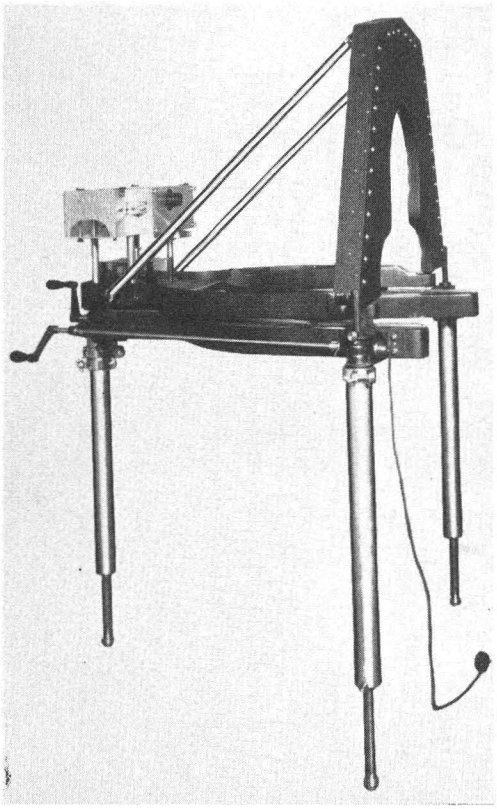

FIG. 8. Recording device for making a form and expression record for a relief portrait.

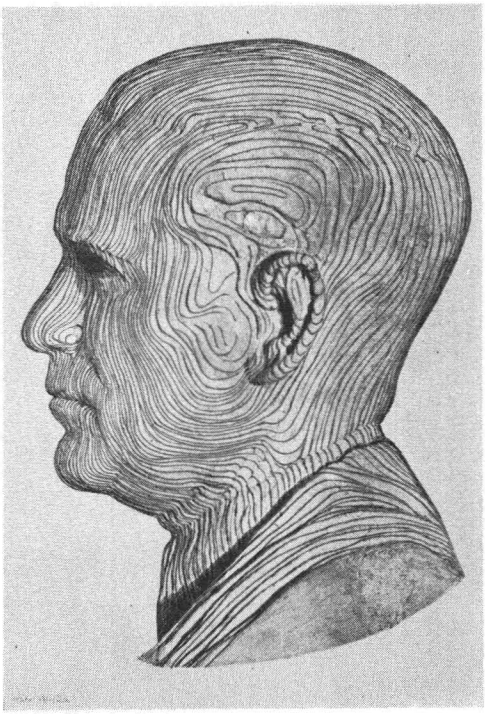

FIG. 9. Paths made by cutter for carving a sculptured relief portrait.

trait, by shaving away the excessive material between the cutting grooves, until they disappear. After the hair has been modeled by hand, and a background added, the relief is ready for making a plaster cast, for the foundry or the marble cutter.

CONCLUSIONS

These new sculpturing methods bring science to art. The sculptor is not limited in his artistic endeavor, but his technique is improved by providing him with a tool that secures a likeness in a sculptured portrait. Miniature portraits for jewelry and for monumental portraits can be made with the same excellence.

The sculptor can carve out a portrait with a slight distortion, if he wants

this in obtaining a more pleasing, a more "idealized" portrait. Obtaining this distortion is difficult when modeling the portrait by hand, but is easily obtained with the new methods. The sculptor's action is like that of the photographer when photographing a tall building and he cannot get vertical lines vertical and parallel on the film plane of his view camera; he simply tilts the back of his camera. Similarly the sculptor, by tilting the film plane of his motion picture camera, can distort his contour pictures so that the top portion or the bottom portion of his portrait become larger or smaller. All points between the top and bottom will be changed in perfect mathematical proportions. This correct mathematical change is important, as thereby the pictures retain the best possible likeness, which the carver can transfer to the carved-out portrait.

The most complicated task of the sculptor—successfully idealizing a sculptured portrait and yet retaining the best possible likeness—can now be done by a simple tilting of the film plane of the camera.

Obviously the more the sculptor idealizes a portrait, the more the likeness suffers. Nature mysteriously, yet accurately records man's inner nature in his face; this is difficult for us mortals to read correctly.

In industry these methods should be taken into consideration in the reproduction of three-dimensional objects which have surfaces that are irregular, difficult to measure, and difficult to machine, such as streamlined surfaces on planes, boats and automobiles.

*Stereoscopic Medical Photography**

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PHOTOGRAPHY, now in its second century, has progressed from the status of a curiosity to a highly respected and necessary scientific tool. This tool, when used in combination with stereoscopic principles and photogrammetrical interpretation, has become as precise as a micrometer or transit in its ability to supply spatial information.

It would be unnecessary to explain to this Society the advantages to be gained by the use of stereograms over the more commonly used two-dimensional processes. It will suffice to say that stereoscopic photographs depict structures which otherwise could not be illustrated, give a clearer concept of shape, comparative size, perspective, and depth, and reveal detail normally obscured in a two-dimensional photograph. In point of fact, many small structures can be more clearly visualized in a stereogram than under magnification or with the unaided eye.

While the value of stereoscopic photography is only beginning to be ap-

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