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Ranz et al.

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[45] **Dec. 18, 1973**

[54] **PHOTOGRAPHIC PROCESS**

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[30] **Foreign Application Priority Data**

July 18, 1970 Germany .... P 20 35 798.6

[52] **U.S. Cl.** .... **96/27 E,** 96/45, 96/116
[51] **Int. Cl.** **G03c 5/04**
[58] **Field of Search** .... 96/116, 27 E, 45, 96/79

[56] **References Cited**

UNITED STATES PATENTS

3,164,470	1/1965	Rebner	96/116
3,637,388	1/1972	Ranz et al.	96/66
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Assistant Examiner—Edward C. Kimlin
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[57] **ABSTRACT**

The brightness and density distribution of an object can be digitally measured photographically by exposing a light-sensitive photographic material at a dot screen or the like and to the object to be measured, and photographically processing the exposed light-sensitive material to produce equidensity images in which different densities of the object are differently represented.

7 Claims, 5 Drawing Figures

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FIG. 1

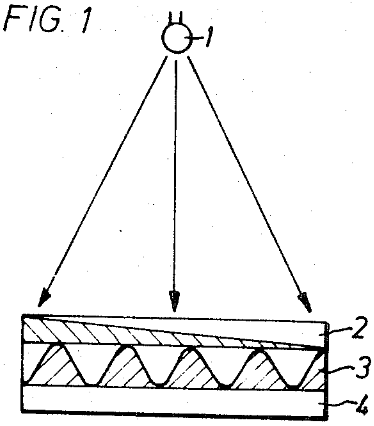

FIG. 2

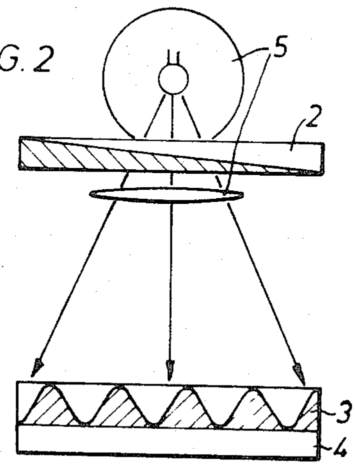

FIG. 3

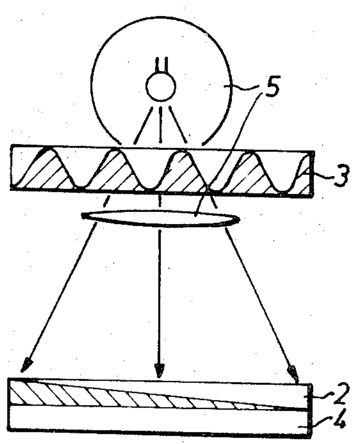

FIG. 4

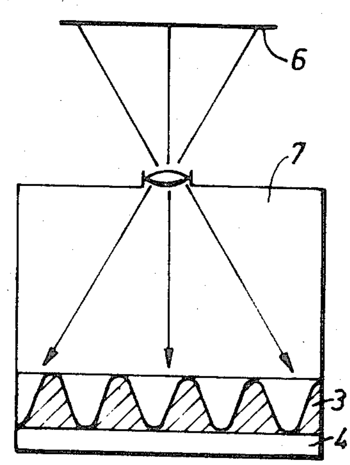

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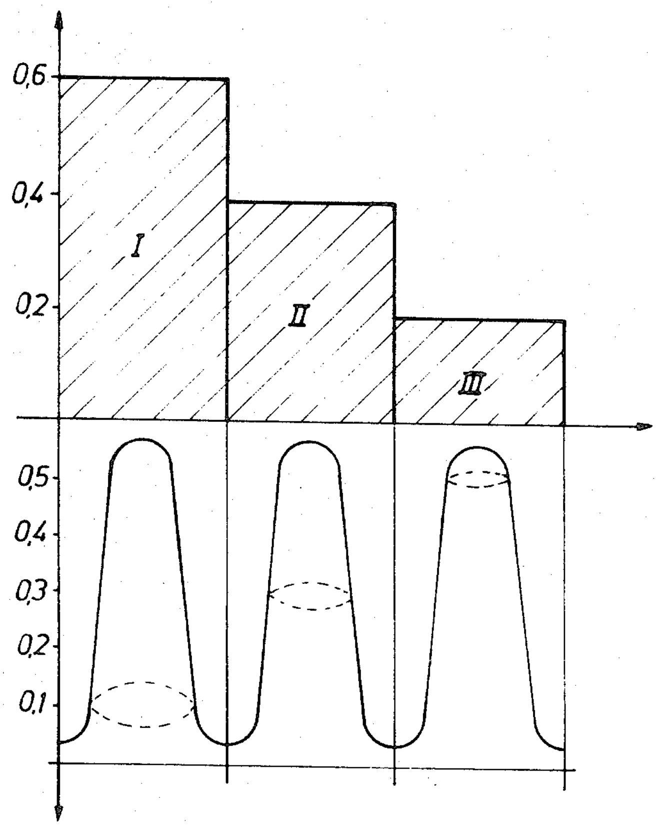
FIG. 5



PHOTOGRAPHIC PROCESS

The invention relates to a photographic process for the digital measurement of brightness or density distributions.

Purely physical photometric methods for the determination of brightness or density distributions of photographic original copies can be used e.g., by means of point by point measurement with photoelectric cells or photometers. However, it is also possible to determine lines or areas of equal density (equidensities) or brightness by photographic processes.

The simplest photographic process for the production of equidensities is one in which a transparent positive is first produced from a negative. The two are then brought in register with each other either exactly or with a slight shift. A copy of this combination of negative and positive then provides a type of equidensity. The disadvantages of this process lie in the difficulties of exact registration of negative with positive and in the distance between the two layers, which may give rise to inaccuracies in the copy.

It is also known to make use of the Sabatier effect for the production of equidensity images. The process enables a negative and positive to be produced in one layer, which is an advantage over the process mentioned above. In this process, the exposed photographic layer is to a certain extent developed, diffusely re-exposed and then further developed to the required extent. Relatively broad and flat equidensities are obtained in this way, which can be rendered more sharp by repeatedly recopying the copies on hard photographic material. The main disadvantage of this process is that the Sabatier effect is difficult to reproduce, especially on account of the necessity to re-expose the layers in a moist state with a very narrow operating range. Moreover, only a few emulsions manifest a sufficient Sabatier effect.

A particularly simple and advantageous process for the production of equidensities by photographic means has been described in German Offenlegungsschrift No. 1,597,509. The photographic material used for this purpose operates by the bromine ion diffusion process. A density diagram with a negative and a positive density curve is obtained.

Although simple equidensities can be produced relatively easily by the known processes, the quantitative determination of a total brightness distribution remains very complicated. The physical processes which require point by point measurement are extremely time consuming. They cannot be applied to original copies which have a relatively complicated heterogeneous density distribution. For the production of equidensities by photographic means, it is necessary to carry out a separate exposure for each equidensity. Electronic instruments such as Isodensitracers (Technical Operations, Boston) and Zytoscan (Zeiss) involve high initial costs.

According to another method, an original copy together with a raster is recopied onto a normal photographic material so that a screened copy is obtained. When this half-tone copy is viewed by dark field illumination, the screen points are altered in such a way that characteristic symbols are obtained for certain relatively narrow ranges of brightness and density. The entire density distribution of an original image is therefore recorded on a copy and becomes measurable. This method has the disadvantage of requiring a device for dark field illumination. Moreover, it is necessary to produce a copy of this dark field image for the purpose of evaluating the results and as a record.

It is among the objects of the present invention to provide a photographic method of measuring the brightness or density distribution by digital measurement, involving a single exposure followed by photographic processing.

We now have found a process for the photographic determination of brightness or density distribution including the steps of exposing a light sensitive photographic material to a screen and to the object whose brightness or density distribution is to be determined, and processing the said light sensitive photographic material by one of the known methods for the photographic production of equidensities.

In general all methods described above for the photographic production of equidensities are suitable for this purpose, but the process according to the present invention is preferably performed with photographic materials from which equidensities can be obtained directly by exposure and normal processing.

Such materials have been described in German Auslegeschrift No. 1,597,509, French Pat. 1,588,117 or U.S. application Ser. No. 766,155 (granted Jan. 25, 1972 as U.S. Pat. No. 3,637,388).

The objects whose brightness or density distribution are to be measured are mainly photographic originals. In addition, however, the process according to the invention also enables the brightness distribution of sources of light to be measured directly by means of a photographic camera, e.g., in the case of illumination measurement. Various possibilities of carrying out the process are represented in FIGS. **1 – 4.**

FIGS. **1 – 3** illustrate various possibilities of measuring the density distribution in a photographic original copy. The simplest embodiment is illustrated in FIG. **1.** The method shown in FIG. **1** comprises the uses a source of light **1,** the original **2,** the screen **3** and the photographic material **4** in which the density distribution is recorded. Original, screen and photographic material are in contact with each other.

FIGS. **2** and **3** illustrate embodiments in which an enlarger **5** is used. The original **2** is enlarged by means of the enlarger **5** and recorded in the photographic layer **4** through the screen **3.** The screen and photographic material are in contact with each other.

The embodiment illustrated in FIG. **3** is similar to that in FIG. **2** but in this case an enlarged copy of the screen **3** is reproduced on the photographic layer through the original **2.**

FIG. **4** shows an embodiment for directly recording the brightness distribution of various sources of light on a photographic film, e.g., for the measurement of sources of illumination, for the measurement of scattered light, for light measurement problems, etc. In this Figure, **6** represents the luminous surface which is to be measured and **7** the camera. The photographic material **4** is situated inside the camera. It is exposed through the screen **3** which is in contact with it.

The photographic material need not necessarily be exposed simultaneously to the screen and the original which is to be measured. For instance it is also possible to expose the light-sensitive layer first to the screen and thereafter to the original.

Moreover, the light-sensitive material onto which is already recorded the screen pattern can be stored and used a long time after for measurements according to the invention. This is advantageous since it simplifies the measurements. If an already screened light-sensitive material is used then the exposure time for the measurement is substantially shortened. In this embodiment it is preferred to record a positive screen on the light-sensitive material.

Practically any type of photographic screens (including colored screen) may be used for the process according to the invention, provided the density distribution of the screen dots is continuous. The usual photoengraving screens or contact screens used for printing processes, for example, are suitable for this purpose. It is preferred to use contact screens because in contrast to photoengraving screens they can be brought into contact with the photographic layers, processing being thereby considerably simplified. A distinction is made between negative contact screens and positive contact screens, which differs from each other in the density structure of the screen dot. Reference may be made in this connection, e.g. to the book by W. REBNER "Die Rasterphotographie mit Distanzund Kontaktraster," publishers Polygraph-Verlag Frankfurt/Main 1967. Both types of contact screens may be used for the process according to the invention. Lens screen foils may also be used.

The process according to the invention enables the total brightness or density distribution of an object to be measured by means of a single photographic operation consisting of exposure and photographic processing to equidensities. In the finished image, the areas of different brightness or density are distinguished from each other by different symbols, e.g., points, circles, circular areas, square areas, squares, and the like. The completed picture is similar in appearance to the printed digital density distributions obtained with the very expensive digitisers (e.g. Zeiss's Zytoscan) except that in the latter case figures or letters are printed instead of symbols.

If exposure is followed by conventional photographic processing instead of by the processing to equidensities according to the invention, a simple screened image of the original is obtained. It is only by the photographic processing to equidensities, either by means of the Sabatier effect or by means of special photographic materials such as those which have been described in German Offenlegungsschrift No. 1,597,509 and which are preferably used for the process according to the invention, that an image of the brightness or density distribution of the object which is to be examined is obtained. The different symbols corresponding to different brightness or density values differ quite clearly from each other even when the difference in exposure or density is quite slight, so that density changes of less than 0.1 can be measured quite clearly. If, for example, the original used in a density wedge having a wedge constant e.g., of $\sqrt[3]{2}$, the density symbols can immediately be associated with the corresponding densities of the original. A complete photometry of the original is therefore obtained as a result of only one exposure and photographic processing or recopying of an original photographic copy. The same applies to illumination measurements, e.g., as illustrated in FIG. 4.

If equidensities are produced with a suitable photographic material then, neglecting the Schwarzschild factor, an equidensity always appears at a constant value of "Light intensity I × Exposure time t ($I \times t$)". If the time t is constant, the intensity I of the light must also be kept constant. I is proportional to the brightness of a source of light or inversely proportional to the density of a photographic original.

For a given exposure time t one therefore obtains the equidensity of a certain density D. If now the original is in contact with the screen or superimposed on it, this density D total is composed of the density of the original and the density of the screen, in other words

$$D_T = D_{original} + D_{screen}$$

As already mentioned above, in the photographic processing to equidensities, e.g., using the photographic material according to German Offenlegungsschrift No. 1,597,509, only a single constant $I \times t$ value is represented as equidensity.

Therefore, without using a screen or raster according to the process of the invention, only a single equidensity line or area corresponding to the constant $I \times t$ value would be obtained. Areas of lower density or brightness would not be recorded. Due to the interposition of the screen according to the present invention, the densities of the original are superimposed on the densities of the screen or the screen dots. A certain density plane of the screen dot is automatically added to the density of the original, resulting in the total density D_T, which corresponds to the constant $I \times t$ value which is recorded as equidensity by the photographic material. If the density of the original is relatively high, only a relatively low density of the screen dot is then added in order to form the constant value of D_T. Conversely, if the density of the original is relatively low, a plane of relatively high density of the screen dot is added to form the constant value of the total density D_T. That means, for a distinct density of the original ($D_{original}$) appears a distinct density of the screen (D_{screen}) as equidensity which has the form of distinct symbols. This principle of the process of the invention is illustrated in FIG. 5. In FIG. 5, the density of the original or of the screen dot is plotted as axis of ordinates against the axis of abscisses, the two densities being one above the other. The areas I, II and III represent steps of different density in the original, the density values of which are 0.6, 0.4 and 0.2.

In the diagram, it has been assumed that the total density D_T for a given exposure time is 0.7. On exposure and photographic processing to equidensities, the equidensity of the density $D_{screen} = 0.1$ appears in that area of the photographic material which corresponds to the density step I ($D_{original} = 0.6$), the equidensity of the density $D_{screen} = 0.3$ appears at the step II ($D_{original} = 0.4$), and the equidensity of the density $D_{screen} = 0.5$ appears at step III ($D_{original} = 0.2$).

Equidensities from different density levels of the screen dot are therefore obtained locally separated from each other. These equidensity areas are represented by different symbols which depend on the form of the recorded density plane of the screen dot. This is indicated in FIG. 5 by the broken contour lines around the density mountains which are intended to represent the different recorded density levels of the screen dot.

The contrast range of an original or the brightness difference which can be covered by this method depends on the density range of the screen dot and also corresponds to this. For an original which has a high contrast range, a screen with a correspondingly high density range should be used, and for an original with a lower contrast range a screen with a correspondingly lower density range should be used. The smaller the density range of the screen dot, therefore, the smaller will be the density range detected in the original and the more accurate will be the possibility of distinguishing small difference of density in the original, and conversely. The size and appearance of the symbols depends on the size and nature of the screen dot and of the line frequency of the screen. The line frequency of the screen should be chosen according to the size of the detail of an original which is required to be examined photometrically.

A further subdivision of the symbols and hence the possibility of finer differentiation of small differences in density can be achieved by producing second order equidensities. This is done by producing equidensities from equidensities of the first order (first exposure on equidensity material) by the usual methods.

When using screens, a continuous density or brightness analysis is obtained, a given range being completely covered without any gaps.

For certain cases, it is advisable to replace the screen with a foil which does not have dots with graduated density distribution but various symbols each of which has a certain density. The different symbols may have clearly distinguishable shapes, e.g. stars, triangles, squares, crosses, letters or numbers etc. A certain number of symbols are chosen, e.g. ten symbols which differ from each other by a density of 0.1. All the different symbols should then be grouped adjacent to each other in the most advantageous arrangement. The size of these groups determines the resolution. This foil may then be used instead of a screen. Again, an equidensity material is exposed, preferably the equidensity film according to German Offenlegungsschrift No. 1,597,509. A particular density of the original or a particular brightness is then always reproduced transparently as equidensity by the same symbol, and the other symbols of the group then do not occur or only those which have an adjacent density. This depends on the desired width of the equidensity. A family of equidensities is therefore obtained after exposure, all the 0.1 density units of the original being characterised by one particular symbol.

When using the symbol foil described above, a brightness difference of 1:10 would be detected in 10 intervals of equal distances apart (26 percent brightness change) or a density range of 1 on an original would be detected in 10 intervals of equal distance apart (0.1 density units).

The nature of the symbols, the difference in density between one symbol and another and the appropriate size and composition of groups of symbols can be altered to suit any given problem. The mode of operation is the same as that described above for a conventional screen.

When using this symbol foil, the density or brightness analysis obtained is not continuous as in the case of screens but is stepwise and the boundaries of adjacent areas can be detected. In this context, the term "screen" is used quite generally to mean conventional screen as well as elements which are equivalent to them in their effect, such as the symbol foils described above.

As already mentioned repeatedly, a photographic material such as that described in German Offenlegungsschrift No. 1,597,509 is advantageously used for the process according to the invention. This material preferably contains a major proportion, up to about 99 percent by weight, of a relatively highly sensitive silver chloride gelatine emulsion and a minor proportion, up to about 25 percent by weight, of a relatively insensitive silver bromide emulsion. The absolute sensitivity of the silver chloride emulsion to light to which the layer is to be exposed should only be slightly less than that of the silver bromide emulsion. Sensitivity ratios of the silver chloride emulsion to the silver bromide emulsion with respect to white light of from 1:10 to 9:10 have been found to be especially suitable. Preferably the emulsions have different spectral sensitivity. It is preferred to use emulsions which contain development nuclei such as those conventionally used e.g., in image receiving layers for the silver salt diffusion process. Suitable development nuclei are e.g., finely divided metals, especially silver or their sulfides and/or selenides. After exposure, the material is developed according to the principle of the bromine ion diffusion process with a developer which is substantially free from potassium bromide. Details about this material may be found in the German Offenlegungsschrift mentioned above.

The developers have the usual composition used for the bromine ion diffusion process. The following are examples of suitable developer substances:

Hydroquinone, developers of the aminophenol series, e.g., p-methylaminophenol and p-phenylenediamine derivatives, developers of the pyrazolidone series, e.g., 1-phenylpyrazolidone-3, and others, alone or in combination with each other.

The potassium bromide content should not exceed 50 mg/l.

A suitable silver halide solvent is e.g., sodium sulfite used in concentration of about 1 to 150 g/l of developer.

The addition of silver halide solvents may be omitted in cases where the developer substance or other additives are themselves capable of functioning as silver halide solvents, as in the case of p-phenylenediamine or its derivatives.

The developers also contain the usual additions of water softeners, antioxidants, substances which render the material alkaline, etc. The pH of the developer is between about 8.5 and 12.5.

EXAMPLE 1

A silver chloride gelatine emulsion is mixed with a silver bromide gelatine emulsion in the ratio of 20:1. The sensitivity of the silver bromide emulsion is 1°DIN above that of the silver chloride emulsion. Both emulsions are prepared by the usual methods. 0.06 g of colloidal silver selenide which has been precipitated in gelatine solution are added to 1 litre of this mixture as development nuclei. The emulsion is cast on a baryta paper support, the amount of emulsion on the support corresponding to about 2 g of silver per m^2.

The material is exposed through a $\sqrt[3]{2}$ step wedge behind a contact screen having a density range of 1.5 according to U.S. Pat. No. 3,164,470 and developed in the following developer at 20°C:

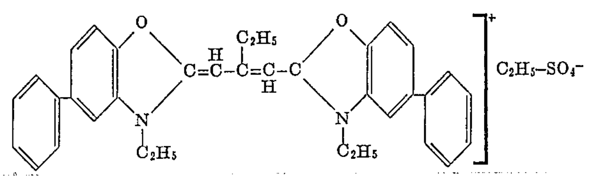
Water	1 litre
Hydroquinone	9 g
Ethylenediaminotetracetic acid	1 g
1-Phenyl-pyrazolidone-3	0.5 g
Sodium sulfite (anhydrous)	120 g

Soda	60 g
Sodium hydroxide	2 g

Development is then stopped in 2 percent acetic acid and the material is fixed, washed and dried. A complete representation of the density distribution of the step wedge is obtained in the symbols characteristic of the different densities.

EXAMPLE 2

A high contrast silver chloride emulsion which has been sensitized to the green region of the spectrum with a sensitizer of the following formula:



is mixed in the ratio of 20:1 with an unsensitized silver bromide emulsion which is sensitive mainly to the blue region of the spectrum. Both emulsions were prepared by known methods. 0.12 g of the colloidal silver selenide described in Example 1 is added to 1 l of this mixture.

The sensitivity to white light (2,800°K) of the sensitized silver chloride emulsion is 1/10 of the sensitivity of the silver bromide emulsion. The emulsion mixture is cast on a support of polyethylene terephthalate (application approximately 4 g of silver per m^2).

Very broad equidensities with steep flanks are obtained after exposure to white light and development as described in Example 1. If the film is exposed behind a yellow filter, the equidensities become progressively narrower with increasing filter density.

In this layer, the width of the equidensities can be varied from a maximum exposure range of 1:10 to a very small exposure range of about 1:1.2 by choosing suitable yellow filter densities.

It is required to measure the illumination of a projector. For this purpose, the photographic layer is inserted in a camera in contact with a contact screen, as illustrated in FIG. **4**. The projector is directed to a white wall. The resulting illuminated area is directly recorded on the film by the camera through the raster. The equidensity range can now be adjusted to its optimum value by suitable choice of a yellow filter which may be arranged e.g., in front of the object lens. After processing of the film as in Example 1, the brightness distribution of the projector is obtained in characteristic symbols which can be associated with exactly determined brightness values.

EXAMPLE 3

The photographic material of Example 2 is exposed in a contact copying device to a contact screen using

white light (color temperature 2,800°K) to produce a positive pattern of the contact screen in the light-sensitive silver halide emulsion layer.

That material which contains the positive image of the contact screen in form of a latent image is used as described in Example 2 for measuring the illumination of a projector with the difference that the camera contains only the light-sensitive material and not a contact screen.

Upon processing a similar result is obtained as in Example 2.

We claim:

1. A process for photographically showing the digital distribution of brightness or density, which process comprises exposing a light sensitive photographic material with at least one silver halide emulsion layer to the object whose brightness or density distribution is to be measured and to a photographic screen of spots each having a continuous range of densities, and then processing the exposed material to produce equidensities in which the spots have appearances that differ in accordance with the local density of the object.

2. The process of claim **1**, wherein the photographic material is simultaneously exposed to the raster and to the object whose brightness or density distribution is measured.

3. The process of claim **1**, wherein the photographic material is first exposed to the raster and thereafter to the object whose brightness or density distribution is measured.

4. The process of claim **1**, wherein the screen is a contact screen.

5. The process of claim **1**, wherein a major portion of the light-sensitive silver halide is silver chloride and a minor portion is silver bromide, the latter being slightly more sensitive to the actinic light used for exposure, and the processing is carried out with a developer which is substantially free from bromine ions and which contains a silver chloride solvent.

6. The process of claim **5**, wherein the silver chloride is optically sensitized and has its maximum of sensitivity at a longer wavelength than that of the silver bromide and the exposure is made through a color filter that adjusts the range of densities to which the photographic material is exposed.

7. A process for photographically showing the digital distribution of brightness or density, which process comprises exposing a light-sensitive photographic material with at least one silver halide emulsion layer to the object whose brightness or density distribution is to be measured and to a raster of spots each having a range of densities in which different density levels have different characteristic shapes, and then processing the exposed material to produce equidensities in which the spots have appearances that differ in accordance with the local density of the object.

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