

Bowker

[54] **SYSTEM FOR ANALYZING
MULTICOLORED SCENES**

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[22] Filed: **Sept. 3, 1971**

[21] Appl. No.: **181,141**

[52] U.S. Cl. **178/5.2 R, 178/5.2 A**

[51] Int. Cl. **H04n 1/22**

[58] Field of Search **178/5.2 A, 5.2 D,
178/5.2 R, 6.6 B, DIG. 34, 6.7 A, 6.7 R,
DIG. 28; 355/38.41; 356/175-178, 2**

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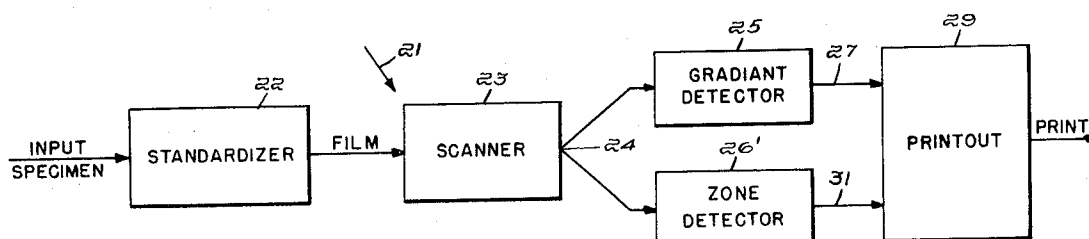
[57] **ABSTRACT**

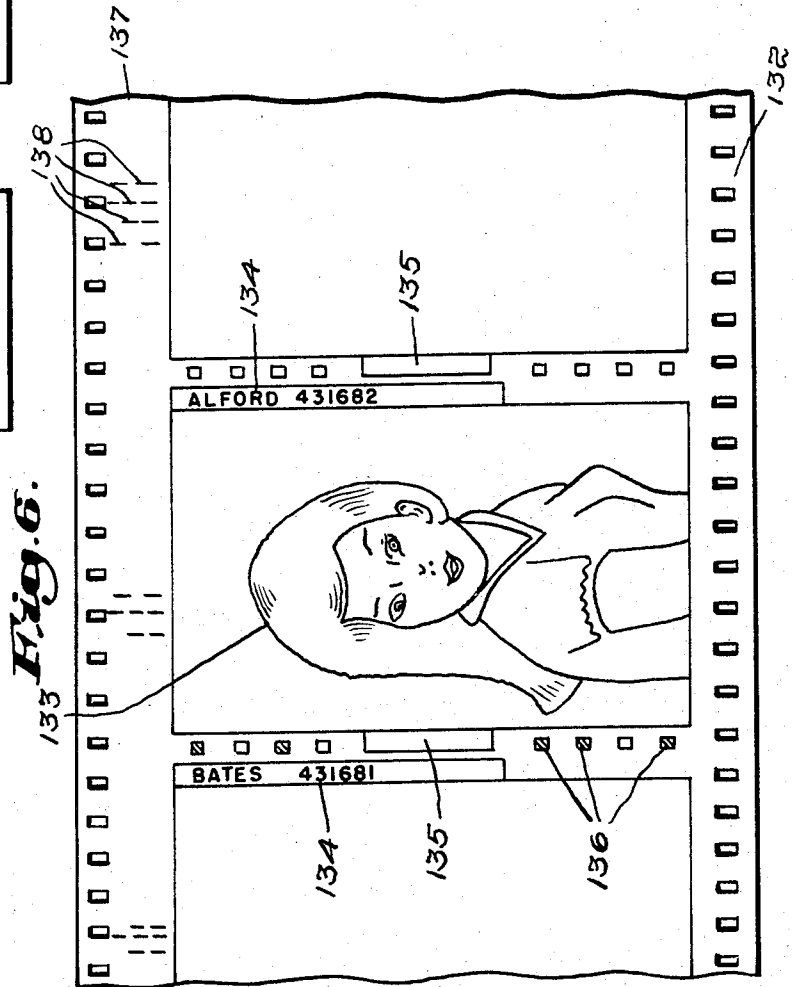
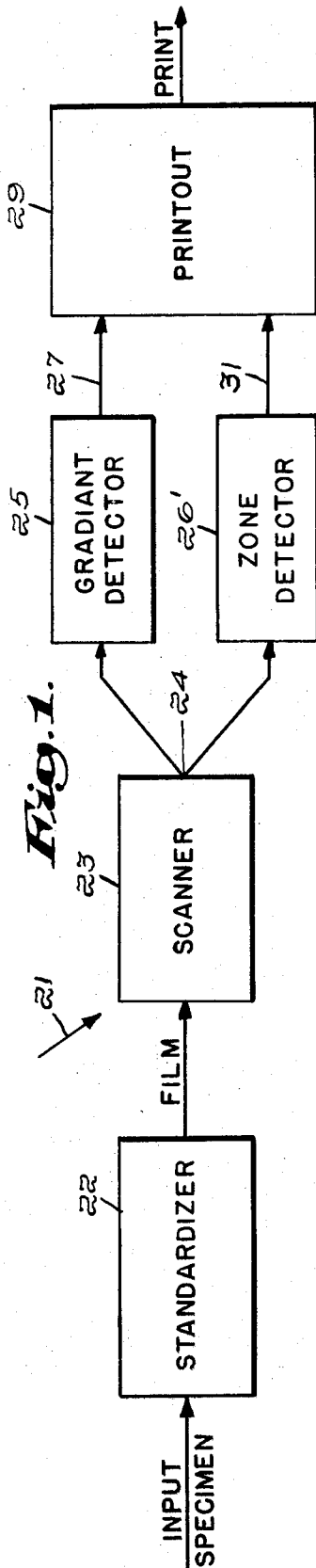
A given scene such as that retained by a colored photograph is scanned both by a high resolution scanner that detects image density gradients and a color analyzer

with lower resolution. Controlled by the gradient detecting scanner is a printer that produces, on an appropriate work surface, a line drawing delineating prominent object boundaries in the image. The color information extracted from discrete areas of the image by the color analyzer is compared by a computer with colors available in a preselected finite set of distinctly colored substances and an appropriate selection is made from the set for each area analyzed. In response to the computer selections, a color indicia printer produces on the work surface a color outline of surface areas geometrically corresponding in position to the discrete areas of the image. The color outline is superimposed on the line drawing but is distinguishable therefrom. Also produced by the color printer within each surface area is indicia representing the particular colored substance selected for application thereto.

In a preferred embodiment, the density gradient and color analyzer scans are made simultaneously in parallel adjacent paths across the image. The line printer responds instantaneously to the output of the high resolution gradient detector. The color analyzer, however, supplies information at intervals along the scan and the color indicia printer prints on each scan line information from the preceding scan line and in a position corresponding to the area from which the information was obtained. The delay in color indicia printout provides time for color evaluation by the computer.

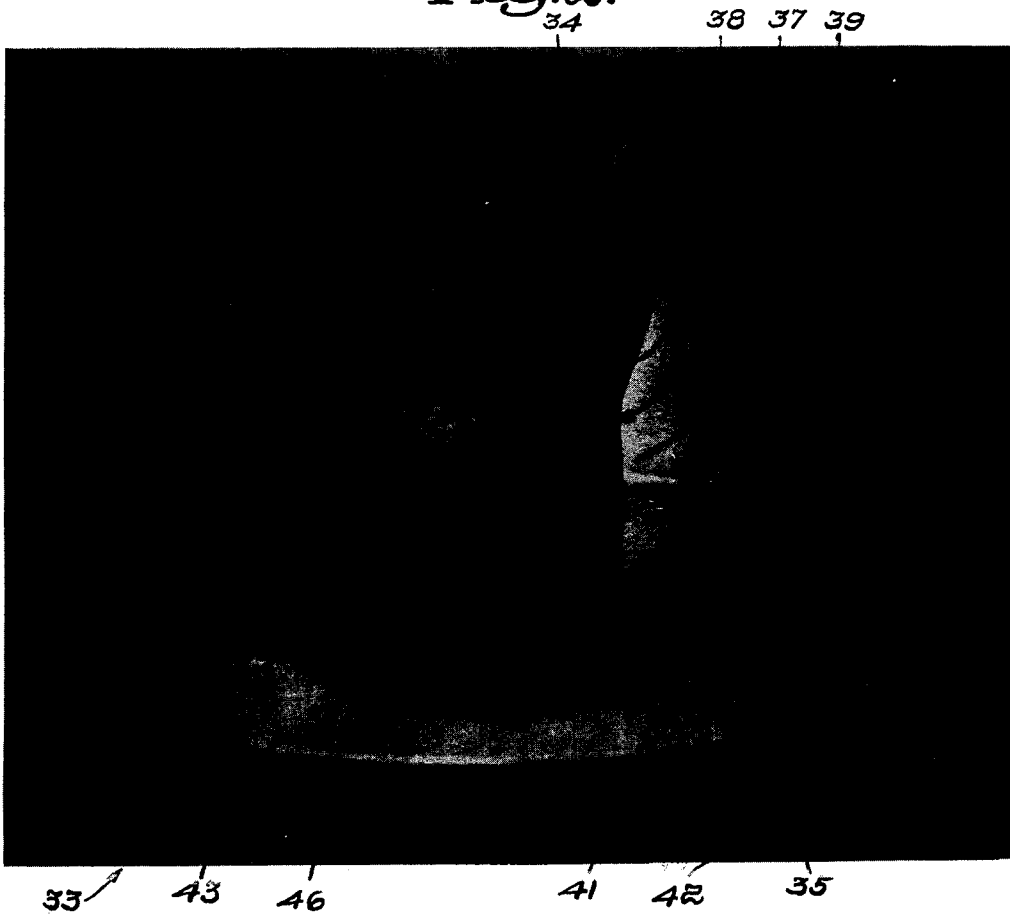
27 Claims, 23 Drawing Figures





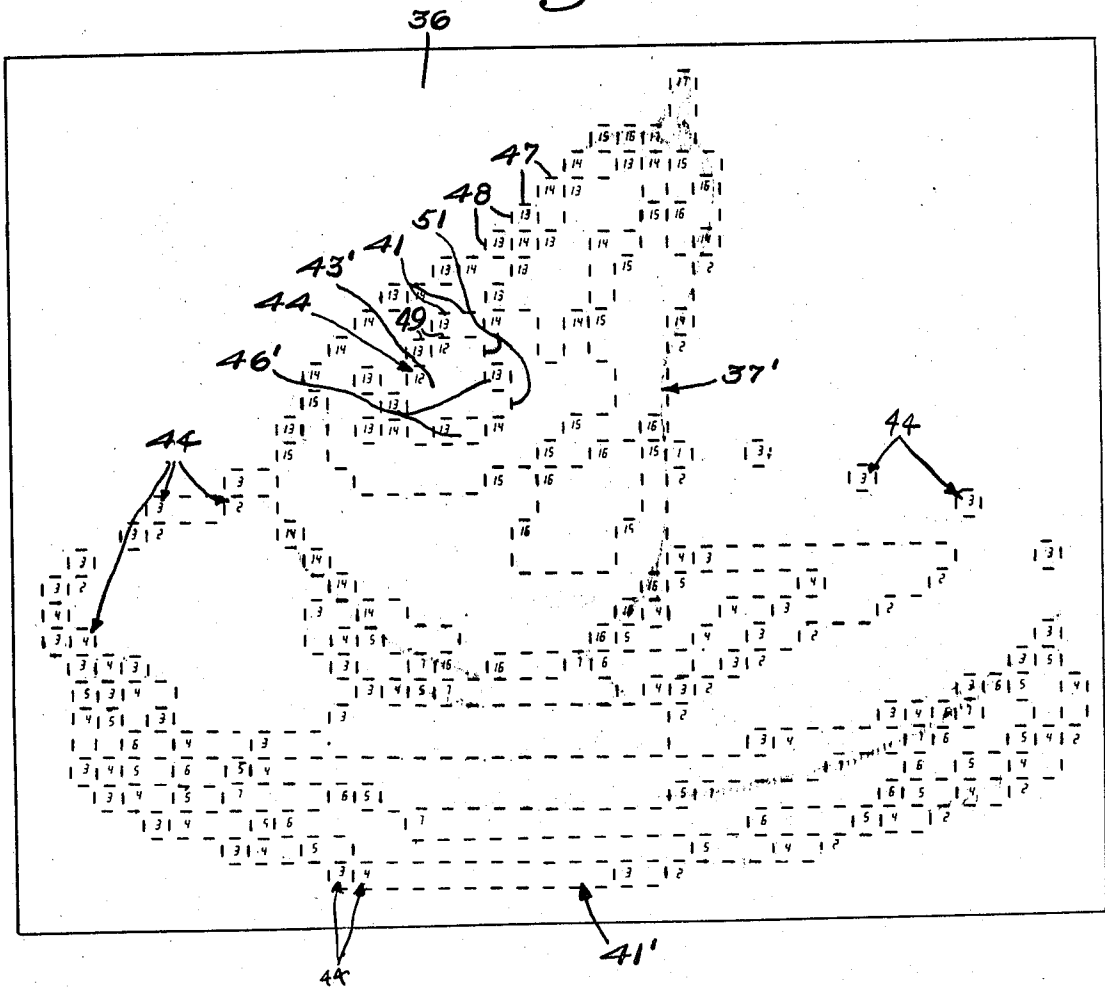
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Fig. 2.



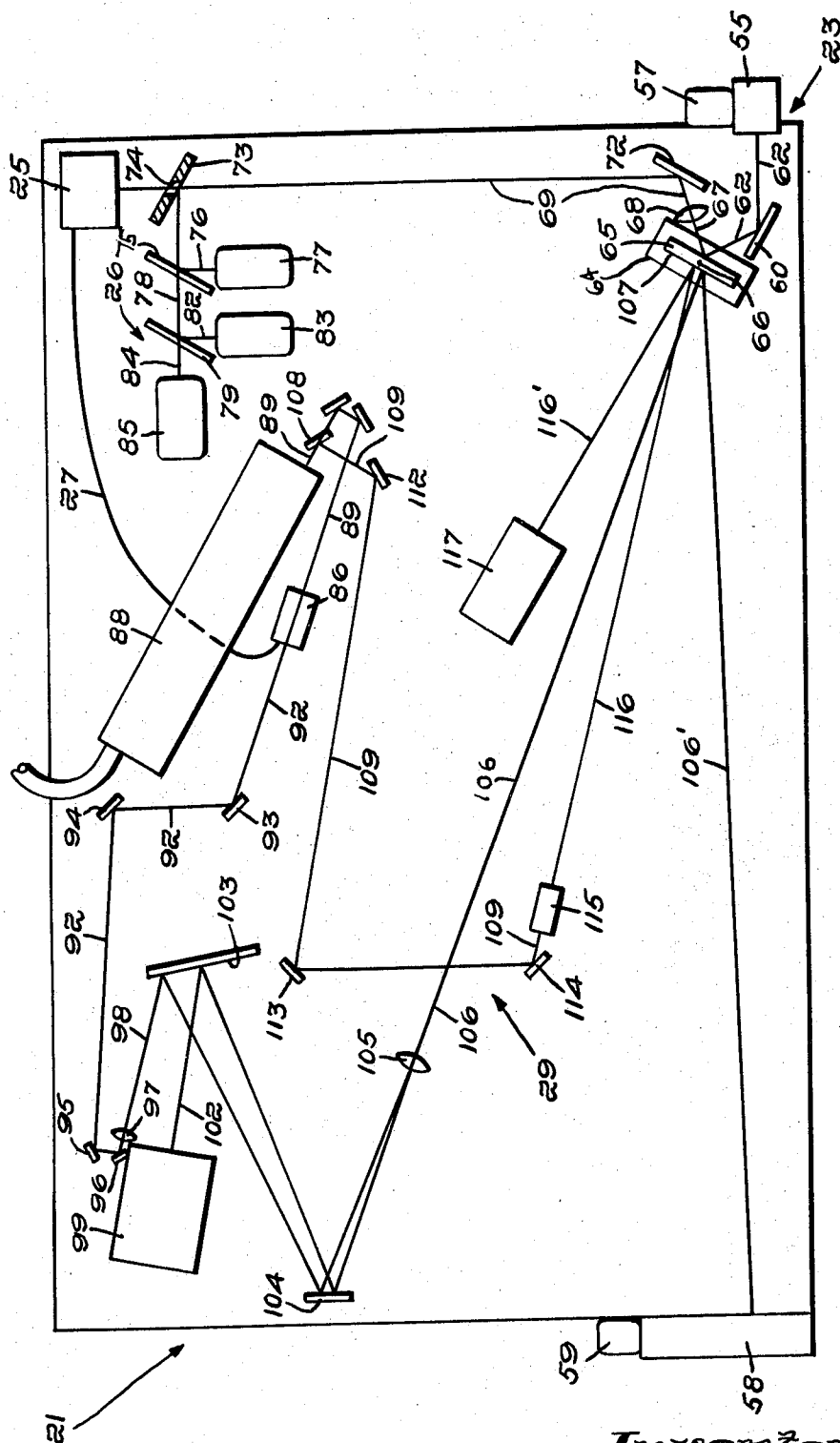
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Fig. 3.



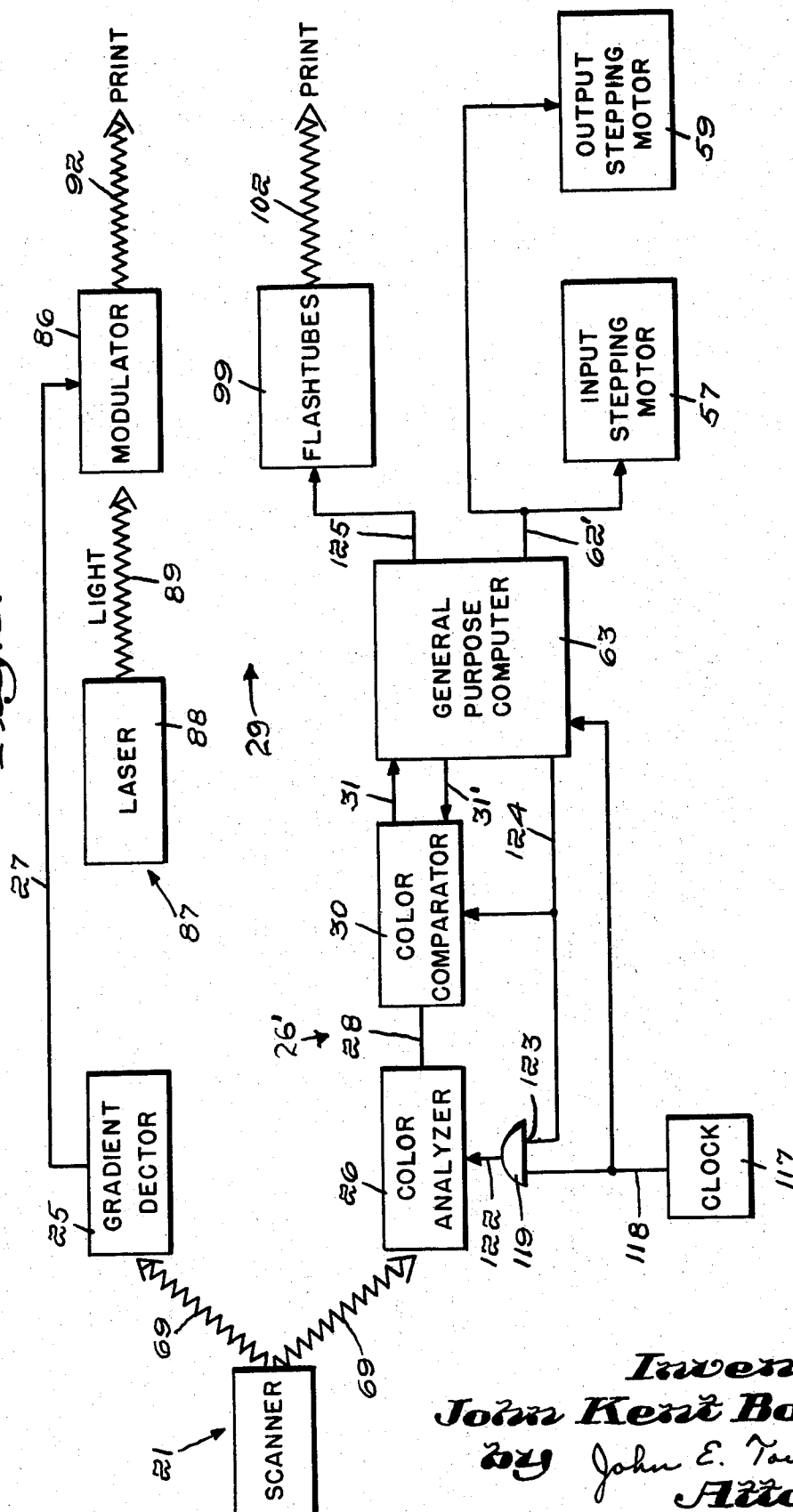
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Fig. 4.

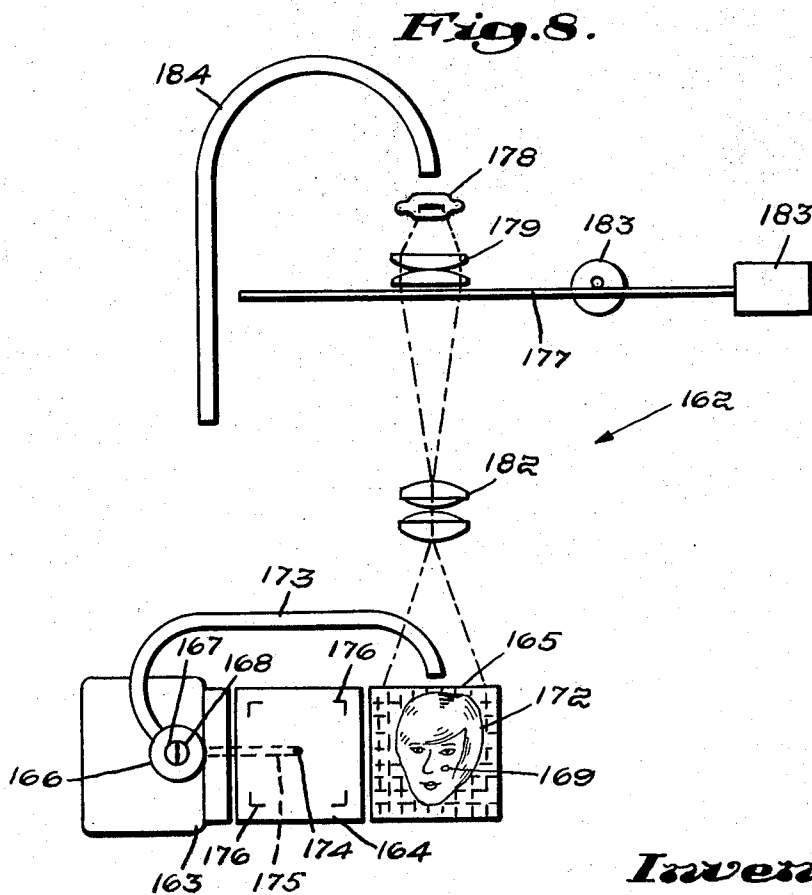
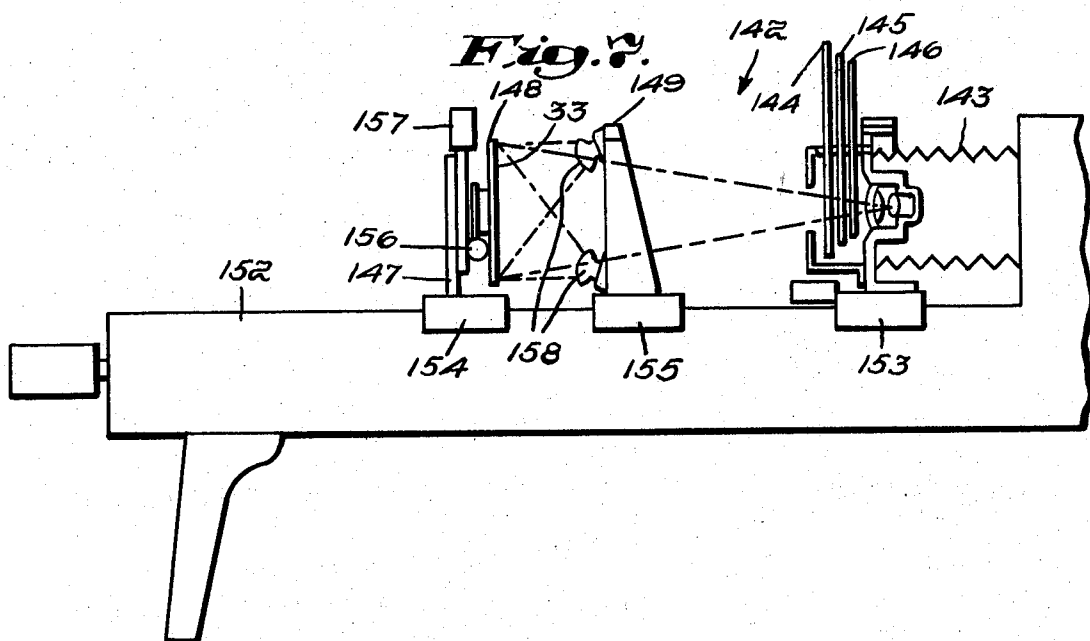


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Fig. 5.

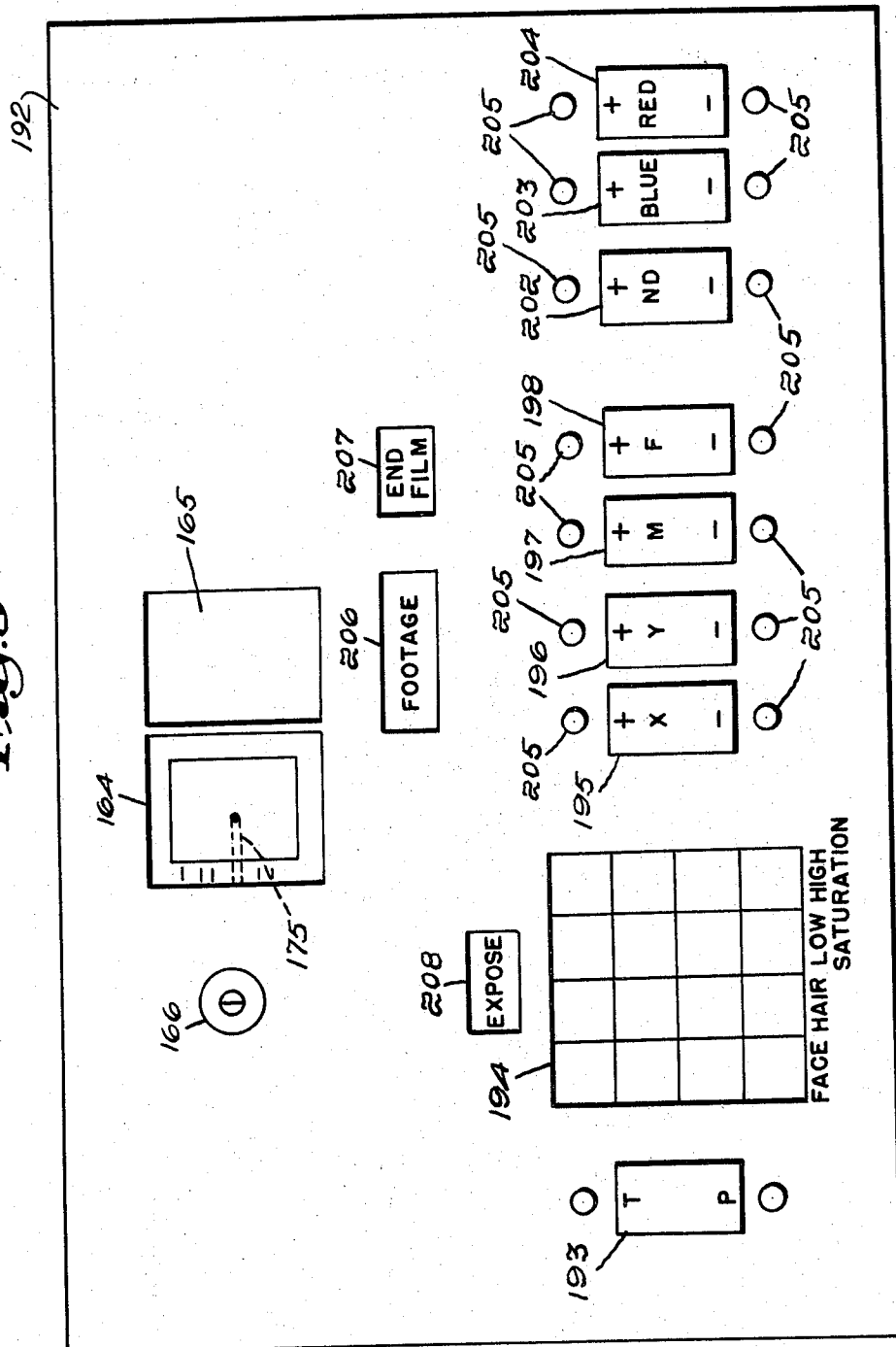


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Fig. 9



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Fig. 10.

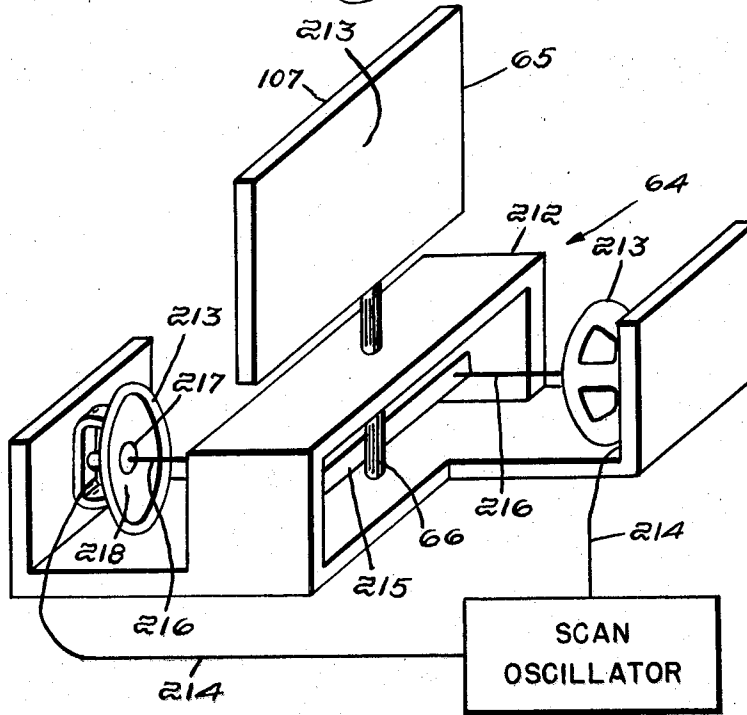
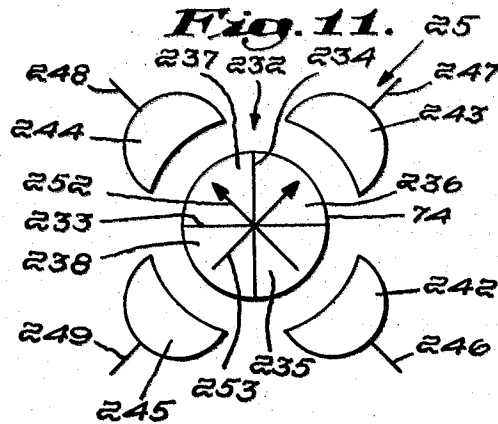
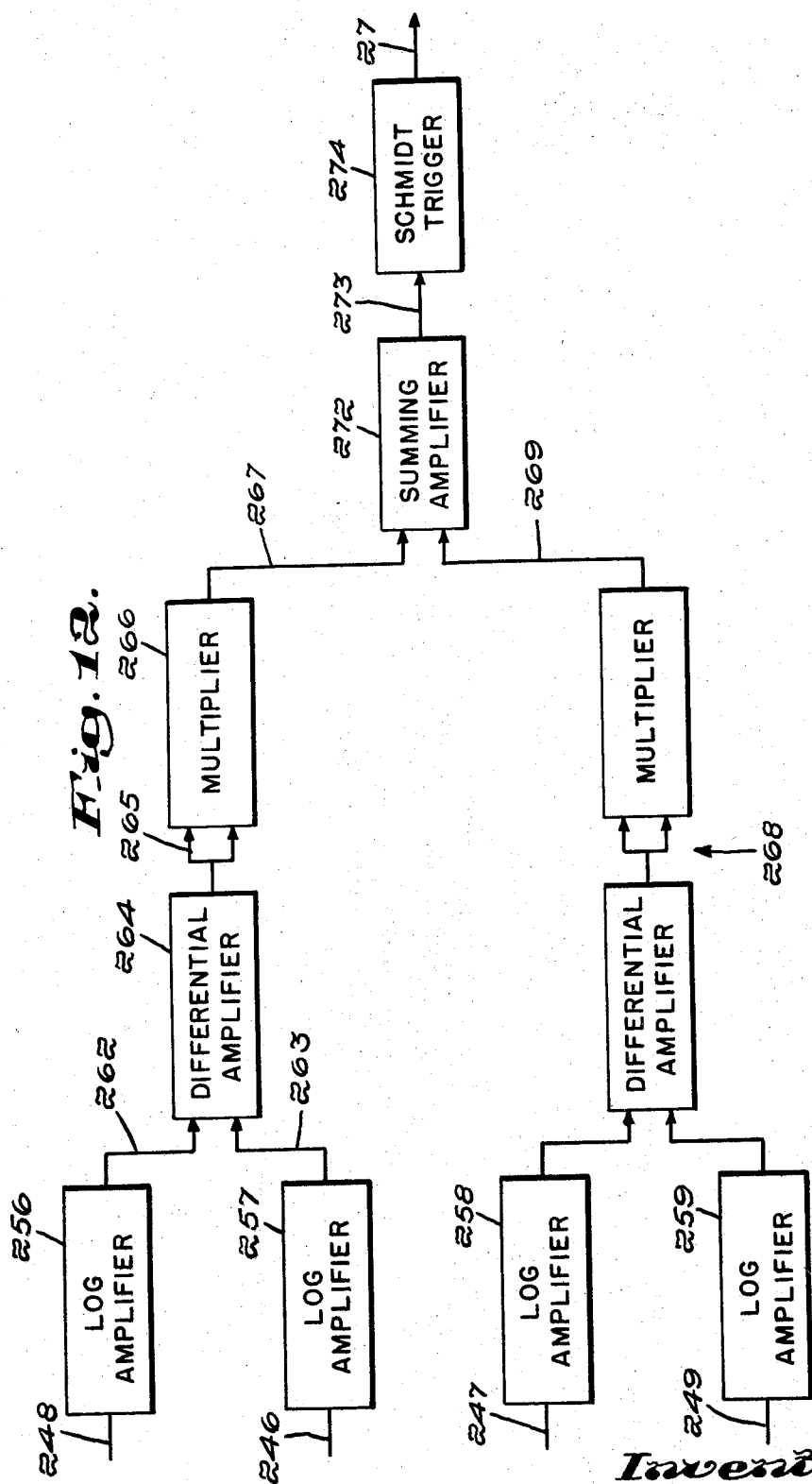


Fig. 11.



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Fig. 13.

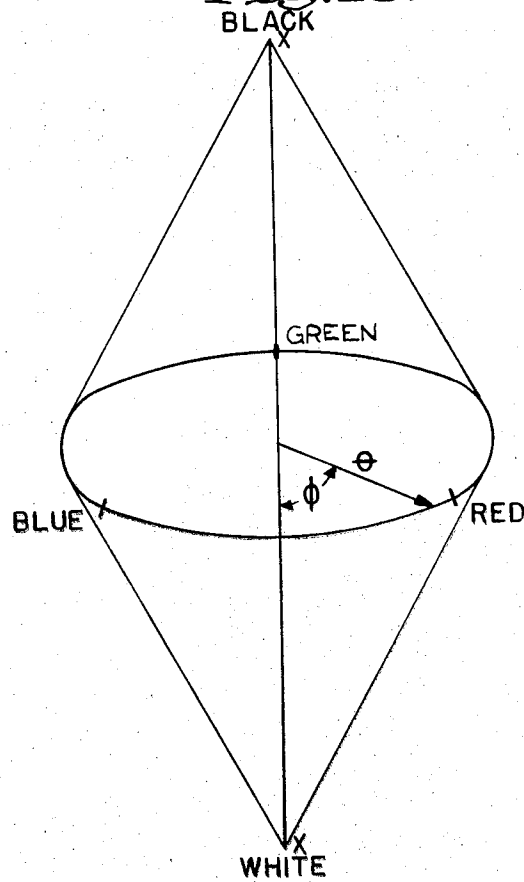
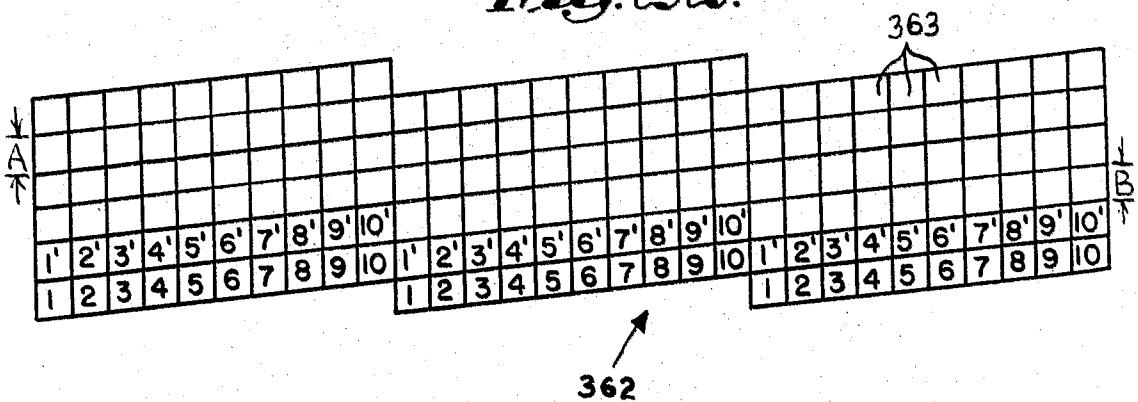
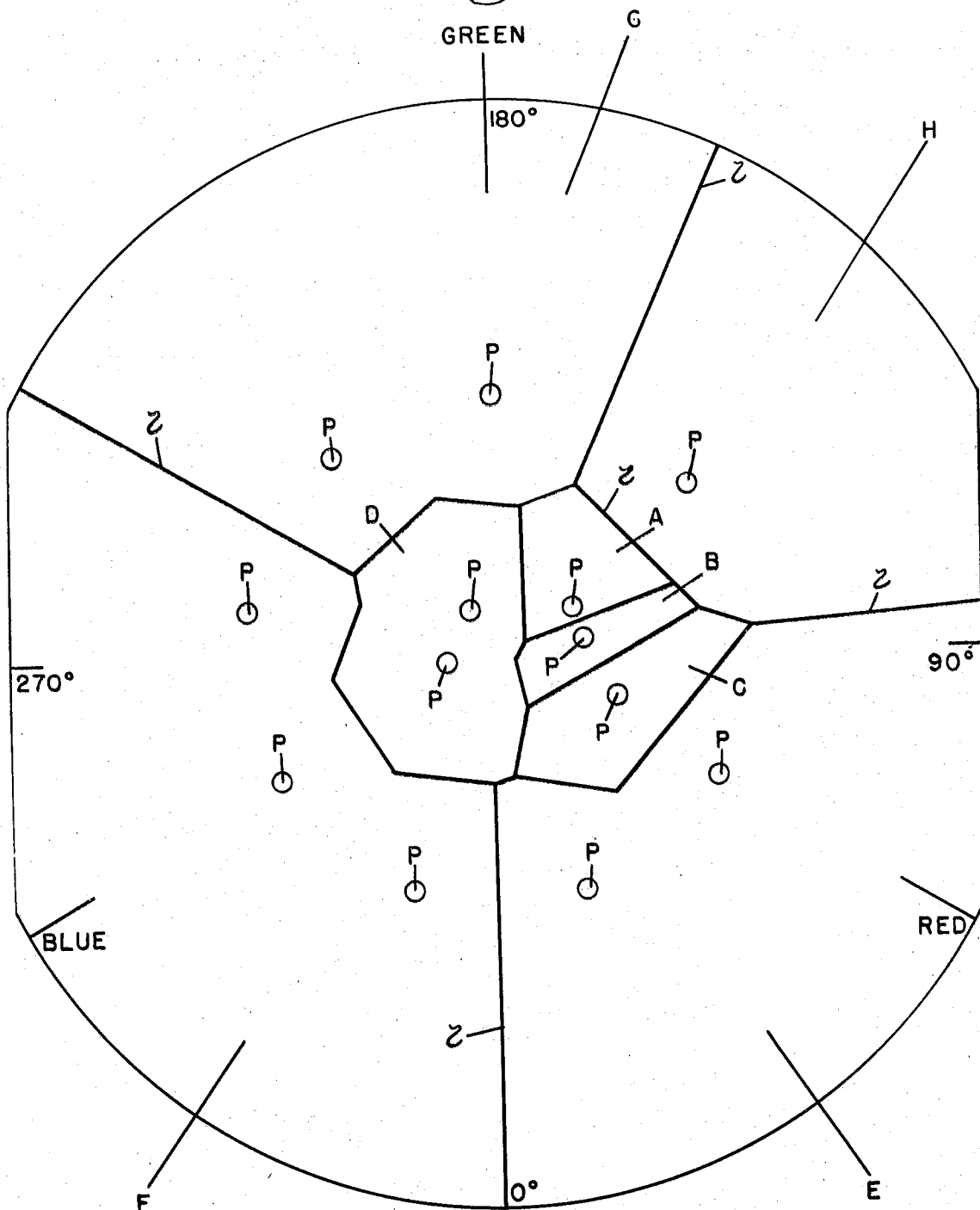


Fig. 22.

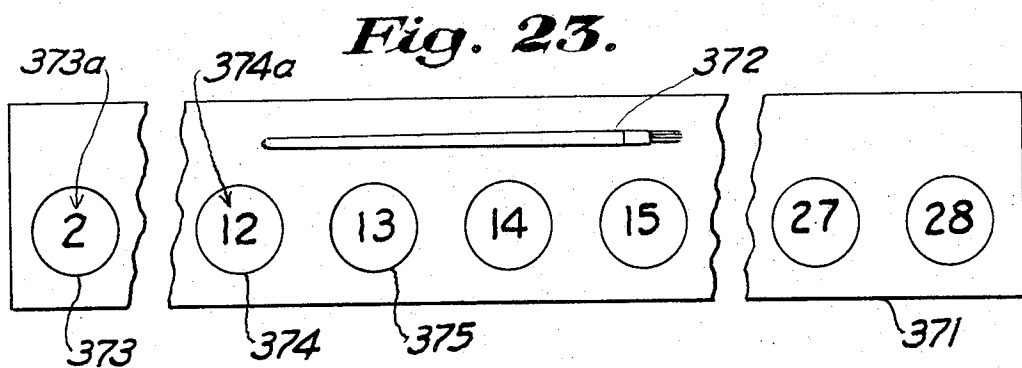
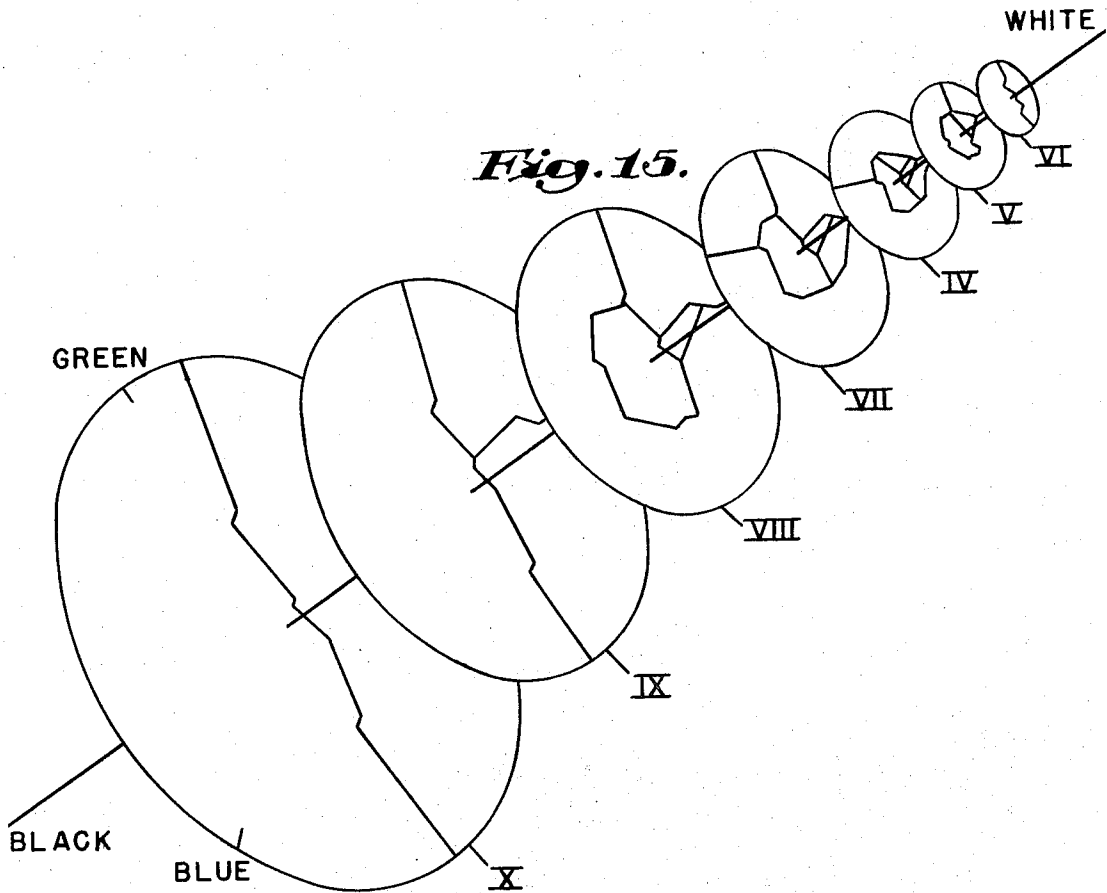


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Fig. 14.

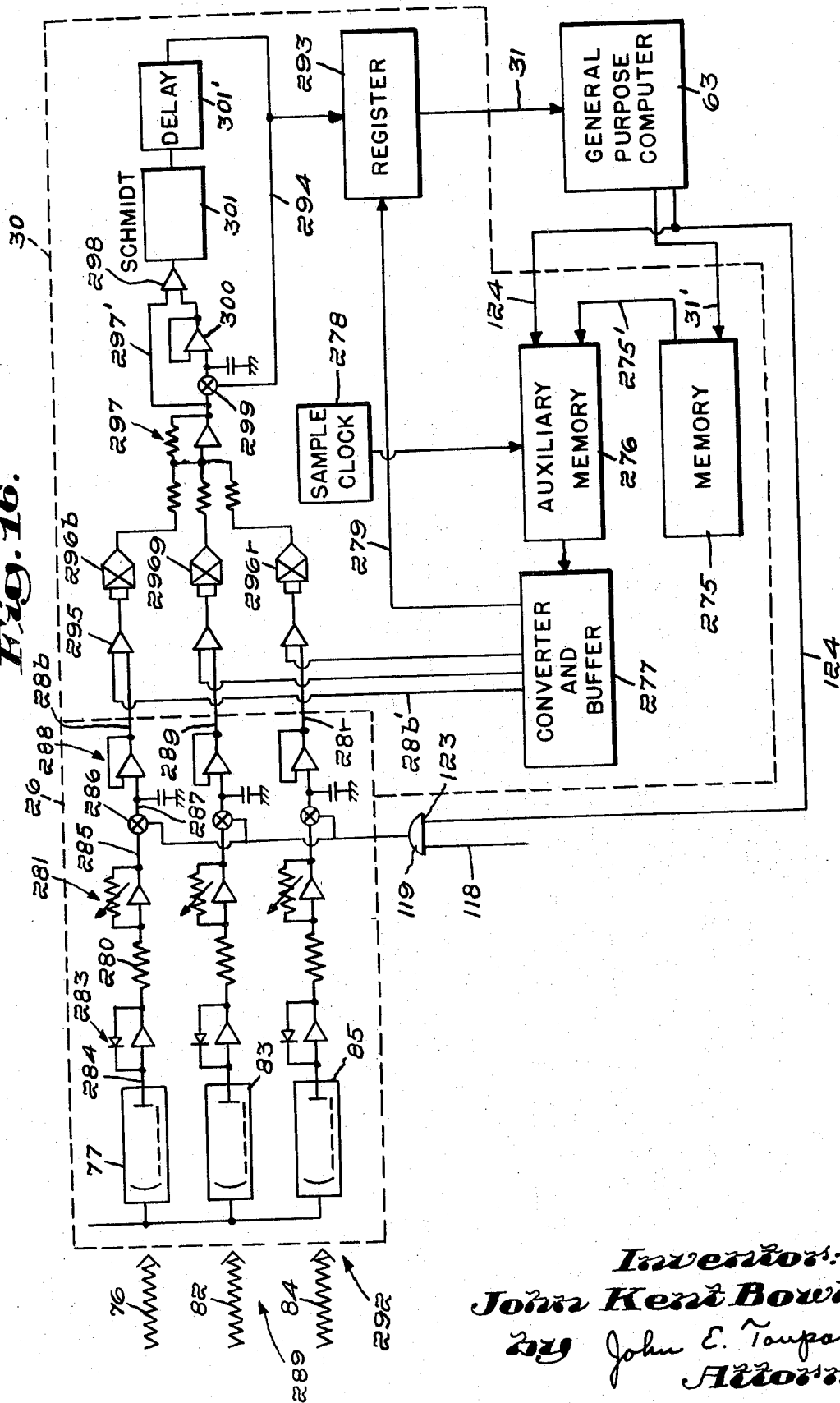


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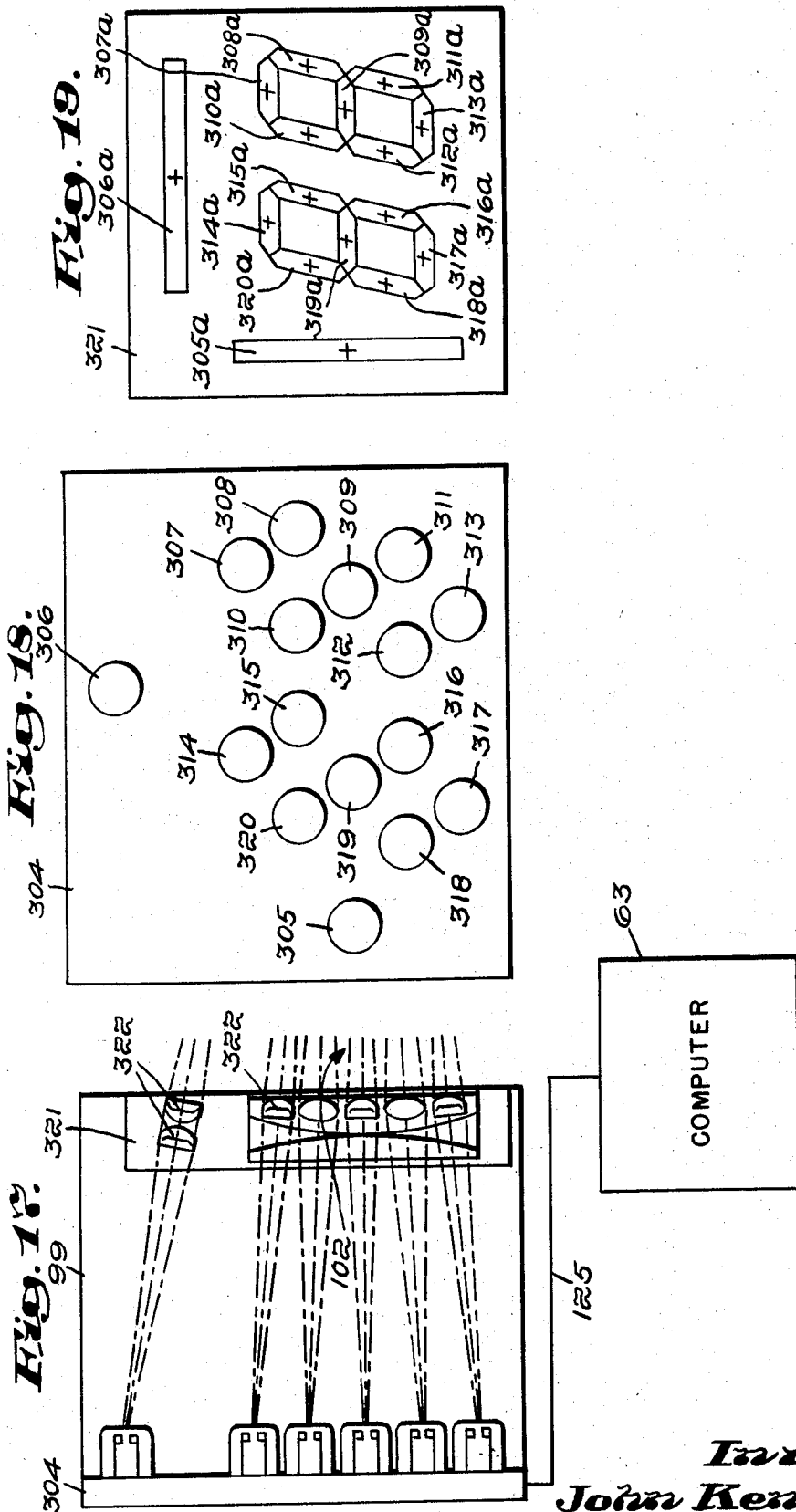


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Fig. 16.

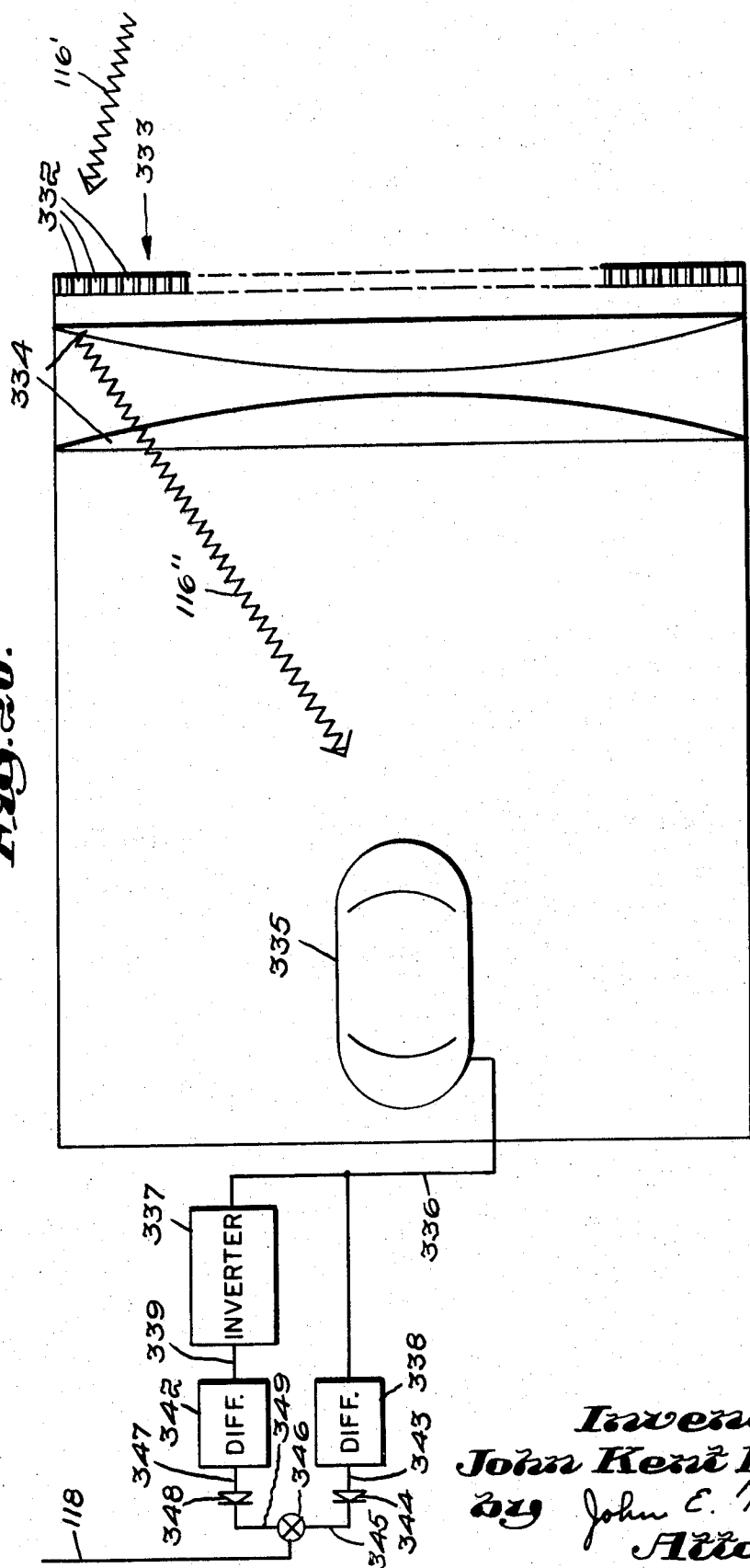


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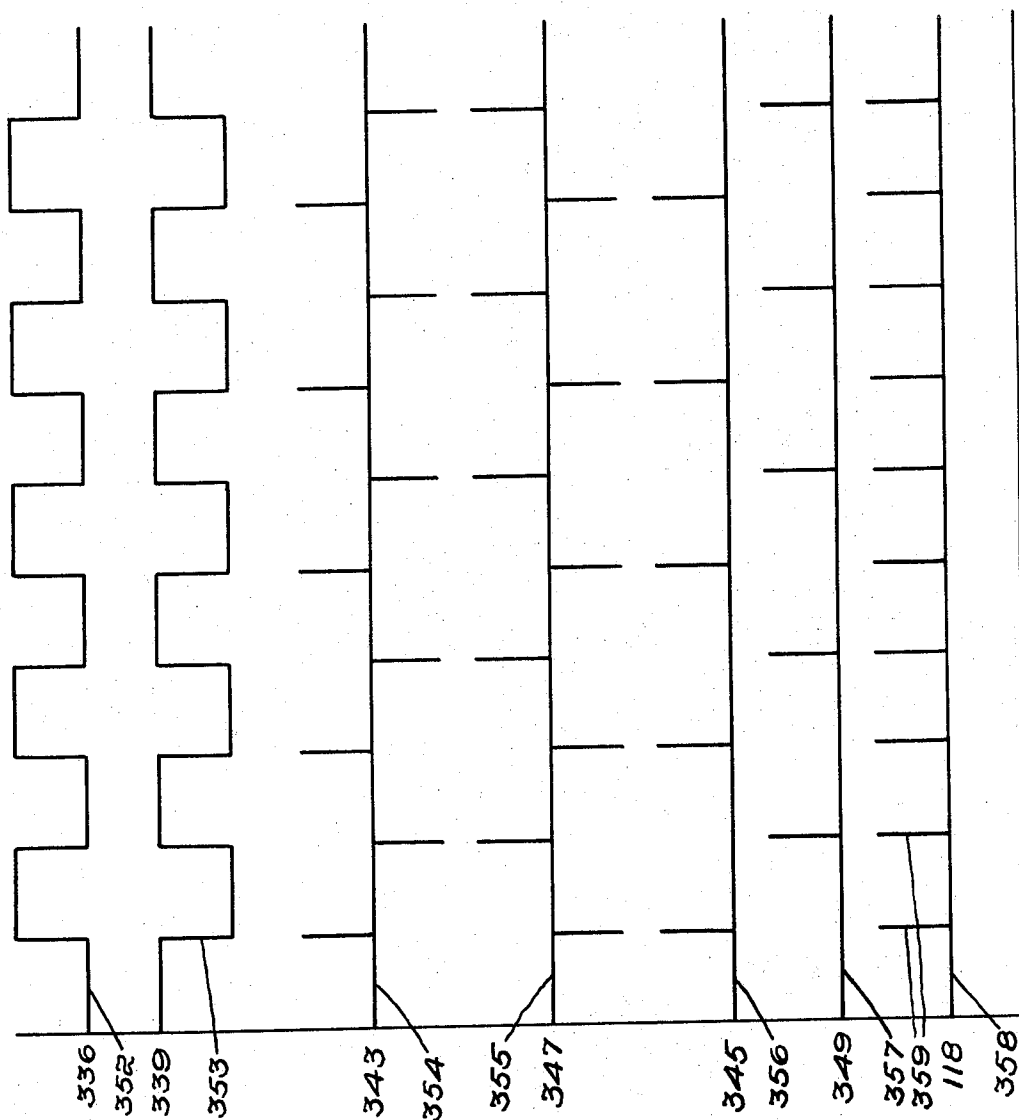
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Fig. 20.



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Fig. 21.



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SYSTEM FOR ANALYZING MULTICOLORED SCENES

BACKGROUND OF THE INVENTION

This invention relates generally to an automatic system for independently analyzing and recording both image detail boundaries and color distribution in particular multi-colored scenes. The system of the present invention is particularly well suited for producing diagrammed work surfaces on which relatively unskilled persons can create renderings of an original scene such as one first recorded on photographic film.

There are available commercially various types of products designed to assist a user in the creation of an artistic rendering. Such products include, for example, fabrics imprinted with designs used during application of decorative stitching and other needlework, imprinted diagrams used during assembly of ceramic mosaics, various types of paint receiving surfaces bearing individually designated color outlines to be followed during the application of oil paints or water colors, etc. One of the best known of the foregoing product types involves the so-called "paint-by-number" techniques for creating oil paintings. According to this technique, a popular oil painting "masterpiece" is used as a model by a commercial artist who generates what might be described as a color contour diagram of the original. Such a contour diagram outlines a plurality of individual areas each bearing a designation for a particular colored paint to be applied thereto. The various distinctly colored paints required are supplied as a palette with the color contour diagram. The paint colors provided in a given palette are determined by the commercial artist who attempts to select for each of the designated areas a paint color corresponding as nearly as possible to the color present in the corresponding area of the original painting. Generally, to minimize cost and reduce the intricacy of the color contour diagram, a limited number of individual colors is provided, typically between 10 and 30.

Because of the substantial human effort required to generate a color contour diagram and to select an appropriate paint palette for use therewith, the variety of original paintings available in paint-by-number form is quite limited. This lack of subject variety in addition to the absence of individuality in a finished product have substantially limited the market for products of this type. A larger selection of subjects and greater intimacy in end results obviously would enhance market potential. Both of these objectives would accrue if a customer could select for rendering any scene with which he is intimately connected and which had been previously recorded on photographic film. For example, a much larger segment of the public would be interested in creating an original oil painting based on a colored photograph of a relative, a close friend, a familiar landscape, an admired architectural object such as one's own home, etc.

Thus, one problem presented above was to provide a set of premixed pigment colors that could be used to create a tonally correct and harmonious oil painting of any preselected photograph. A solution to the problem, however, was not available with the conventional color reproduction techniques employed, for example, in the fields of photography, color television and printing. Color reproduction systems in these fields rely on Newtonian theory that sets forth the generalization that all

colors can be defined in terms of fixed primary colors R, G and B. A specific color $\bar{Q}$ is then defined as a vector in three-dimensional space equal to $r\bar{R} + g\bar{G} + b\bar{B}$ where the values r , g and b are the tristimulus values of the color with respect to the particular set of primary colors R, G and B. A color to be reproduced is first spectrally analyzed by a suitable device such as a color television camera, to determine the component values r , g and b . These values are then used to selectively control the proportionalities of primary color light sources used to reproduce the color. The reproduction can entail an additive process in which appropriate values of the three primary colors, such as the commonly used red, green and blue, are added or a subtractive system in which a tri-color set such as cyan (minus red), magenta (minus green) and yellow (minus blue) absorbs desired amounts of incoming primary colors. Color television, for example, is strictly an additive process in which red, green and blue phosphors are selectively activated to produce a desired color while color photography is a subtractive process in which appropriate thicknesses of color layers subtract light from incident white light to produce the desired color in either transmitted or reflected light. In all such analytical color reproduction systems, however, a substantially infinite variation of the reproduction color stimuli is available to reproduce the measured tristimulus values of the original color. Thus, the reproduced color comprises appropriate values of each of the primary colors that synthesize the color desired.

It will be apparent that these conventional color reproduction techniques are not applicable to the present problem in which color selections must be made from a palette consisting of premixed paints. The color space represented by such a palette is similar to the digitized hyperspace of n dimensions common to object recognition, and is quite different from conventional analytic color space.

In addition, classifying all areas of the photograph as being one of the available colors does not convey sufficient information to the artist to permit him to complete the rendering. Sharp detail boundaries in the input photograph should be distinguished from gradual color transitions if these characteristics are to be recreated in the rendering. For example, in creating the rendition of a spherical object such as an apple, the various colors applied to the object should be blended rather than applied so as to define sharp boundaries. Conversely, a sharp discontinuity such as would appear between the object and a different colored background should appear also as a sharp boundary in the rendition. Therefore, the work surface provided should distinguish between sharp detail boundaries and gradual transitions so as to apprise the artist of where and when not to blend the applied paints.

The object of this invention, therefore, is to provide an automatic system for producing sets of diagrammed paint boards and associated palettes that can be used to generate tonally correct and harmonious oil paint renderings of original scenes as retained, for example, by color photographs.

SUMMARY OF THE INVENTION

The present invention is characterized by an automatic system for producing a diagrammed work surface that both illustrates sharp detail boundaries and identifies gradual color transitions in a given multi-colored

scene. In a specific application, distinctly colored substances are then selectively applied to the work surface to create an artistic rendering of the original scene. Preferably, a colored photograph is used as a basis for producing the work surface retaining diagrams that define general areas on which distinctly colored paints can be applied to create a rendering of the picture imaged on the photograph. According to the invention there are selected and identified, in a given colorimetric system, the boundaries of color domains corresponding generally to color tonalities of the photograph. A distinctly colored oil paint is then provided to represent each of the color domains and each paint color is given an identifying designation. Scanning through discrete portions of the photograph with a color analyzer establishes in the given colorimetric system the coordinate positions of the colors present in each of the portions scanned. Next, a computer search is made to determine which particular one of the selected color domains encompasses the color coordinate position of each of the analyzed colors in the photograph. Finally, discrete zones on the paint receiving work surface that correspond geometrically in position to the discrete portions scanned in the photograph are located and there is applied by a printout mechanism to each work surface zone the designation for that paint color representing the color domain that encompasses the color coordinate position of the analyzed color in the geometrically corresponding portion of the photograph. A gradient detector scans in synchronism with the color analyzer and detects outlines of distinguishable objects present in the photograph. The detected object boundary outlines are superimposed by the printout mechanism on the color designated zones of the work surface. Together, the zone and boundary outlines guide the artist during the application of paints to the work surface.

According to a preferred embodiment of the invention, the above described step of determining which color domain encompasses the color coordinate position of each analyzed color entails the prior step of selecting in the given colorimetric system a plurality of particular color coordinate points such that planes established by other points equally spaced from the particular selected color coordinate points define the boundaries of the color domains. A comparison is then made by computer to determine which of the particular selected color coordinate points is nearest the coordinate position of each analyzed color from the photograph. Because of the above noted coordinate point selection method, the nearest particular point lies in and thereby establishes the color domain encompassing the color coordinate position of each analyzed color. This method of coordinate point comparison permits the location of an appropriate domain for each analyzed color with conventional computer memory techniques.

One feature of the invention is the use of a three-dimensional tristimulus colorimetric system in the methods described above. Utilization of the tristimulus colorimetric system facilitates a determination of the color coordinate positions of colors in the photograph in that conventional primary color analyzer systems can be employed to analyze the photographs. According to a preferred embodiment of the invention, however, the original selection of color domains is first made in a three-dimensional polar coordinate colorimetric system utilizing hue, saturation and lightness as

color components. Such a colorimetric system is more perceptible psychologically and therefore simplifies the selection of appropriate color domains. Once selected, the coordinates defining boundaries of the selected color domains are mathematically transformed into equivalent coordinates of the tristimulus colorimetric system desired for analysis of the photograph.

According to the featured embodiment of the system described above, the step of selecting a plurality of color domains and then providing a palette consisting of a distinctly colored paint for each domain entails the selection of a plurality of sets of color domains and a corresponding palette for each. The tonal variations in each selected color domain and corresponding palette set are unique. For example, one set might approximate the tonalities present in a photographic subject of light skin and blond hair while another set might correspond to the tonalities present in a photograph of a subject with dark skin and black hair. The particular set of color domains and corresponding palette used in the above described system is then selected from this plurality of sets after a comparison thereof with the particular photograph to be rendered. In this way individual palettes, each composed of a relatively small number of distinctly colored paints, can be employed to produce harmonious and relatively tonally correct renderings of photographs with widely different tonal representation.

Another feature of the invention is a synchronization system that facilitates simultaneous and synchronized scans of the photograph by the color analyzer and the gradient detector and of the work surface by the printout mechanism. Preferably, a rotatably reciprocating two-sided mirror is used as a synchronizer. The photograph is illuminated and the analyzing scanning beam is generated as the reciprocating mirror reflects light from different areas of the photograph onto a focusing lens. The work surface is generated on a sheet of photosensitive material by a printout beam reflected from the other side of the mirror. This insures both spacial and temporal synchronization of the input and output, provided the delay between scanning and printout is small.

Another feature of the invention is the use of distinct and separately modulated printout beams for recording the information derived by the gradient detector and the color analyzer. The separate printout beams are complemented by a synchronized delay system that produces intermittent color sampling by the color analyzer and subsequent printout in an interlace pattern. Since the gradient detector is a substantially instantaneously responsive device, the image detail boundary information detected thereby can be printed out continuously on the work surface by the synchronized writing beam output of the two-sided mirror, as described above. However, analyzation and identification of the various color zones by the color analyzer requires several milliseconds, and scan rates slow enough to accommodate immediate printout of color identification information would seriously limit the output capacity of the system. Therefore, after any zone is sampled and identified, the color information concerning that zone is placed in a memory of an interlace control system. Subsequently, during a following scan, when the position of the color output scanning beam corresponds with the position of the aforementioned zone, the interlace system retrieves the information in the memory and applies it to the printout mechanism. The path of the color printout beam is displaced with respect to the

boundary printout beam to compensate for the spacing between successive scans.

Another feature that improves the efficiency of the system is a resolution control that establishes different resolutions for the gradient boundary and color zone detectors. In a preferred embodiment the gradient detector is provided with substantially greater resolution than the zone detector. Detail boundaries are therefore detected from small and closely spaced sampling areas as compared to those used for color analysis. Preferably, the zone detector samples an area of the magnitude of 100 times the size of that sampled by the gradient detector. This relationship provides the high resolution desired for detail boundary detection without seriously limiting scanning speed by burdening the zone detector with an excessive number of computations. In this connection, it should be realized that reduced resolution in the zone detector does not degrade the ultimate performance of the system. According to conventional techniques, oil paints of different colors are substantially blended near boundaries to create desired results rather than being applied to distinct areas. Such blending techniques would tend to negate the effect of a high resolution zone detector.

Still another feature of this invention is the provision of a standardizer that operates to produce input scenes of uniform size and tone. Standardization of the input scene enhances the speed capability of the system. Preferably, all input scenes are reproduced in a given format such as on a 70 millimeter transparency strip. This technique accommodates a simultaneous recording of auxiliary information useful in the overall process. For example, fiducial, or code marks are recorded to provide control signals for the computers employed in the system. In addition to the obvious benefit of properly cropping each input image while photographing, the standardizer compensates for variations in quality and color balance in the input prints with corrective filters. Also, the system is simplified in that scanning can be controlled by the fiducial marks rather than computations such as scan counting. Printout on a continuous roll is also facilitated permitting the size and shape of the prints to be altered without any change in the system.

DESCRIPTION OF THE DRAWINGS

These and other objects and features of the present invention will become more apparent upon a perusal of the following description taken in conjunction with the accompanying drawings wherein:

FIG. 1 shows a basic block diagram of a system for analyzing multi-colored scenes;

FIG. 2 shows a sample input specimen;

FIG. 3 shows an output print obtained by the operation of the system shown in FIG. 1 on the specimen shown in FIG. 2;

FIG. 4 shows a preferred physical layout for the optical components of the system shown in FIG. 1;

FIG. 5 shows a block diagram of the system shown in FIG. 1;

FIG. 6 shows the format of the transparency strip used to record the input specimen;

FIG. 7 shows a preferred embodiment of a camera used to produce the transparency strip shown in FIG. 6;

FIG. 8 is a schematic diagram of the viewing system used in the camera shown in FIG. 7;

FIG. 9 shows a preferred operator control panel;

FIG. 10 shows the scan position control used in the embodiment shown in FIG. 1;

FIG. 11 shows the resolution control aperture and associated photodetectors used in the gradient detector in the embodiment shown in FIG. 1;

FIG. 12 is a block diagram of the gradient detector;

FIG. 13 is a munsell color diagram;

FIG. 14 shows a constant value plane of the munsell diagram that has been divided into distinct color domains;

FIG. 15 is a three-dimensional color diagram comprised of a plurality of constant value planes such as the one shown in FIG. 14;

FIG. 16 is a schematic diagram of the zone detector used in the embodiment shown in FIG. 1;

FIG. 17 shows the second radiant energy source used in the embodiment shown in FIG. 1;

FIG. 18 shows the support used in the radiant energy source used in FIG. 17;

FIG. 19 shows the aperture mask used in the radiant energy source shown in FIG. 17;

FIG. 20 shows a color block and associated circuitry used in the embodiment shown in FIG. 1;

FIG. 21 shows waveforms present within the circuitry shown in FIG. 20;

FIG. 22 shows an interlace pattern used in the embodiment shown in FIG. 1; and

FIG. 23 shows a typical palette that is supplied with the printout guide.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1 there is shown a basic block diagram of a preferred system 21 for automatically analyzing multicolor scenes. A multicolor scene (not shown) is photographed by a standardizer 22. A plurality of scenes or input specimens are used and the standardizer 22 produces a strip of 70 mm transparencies from the plurality of input specimens. This film strip (not shown) is placed in a scanner 23 that detects from the images depicted thereon certain boundary detail and color information as described below. An output 24 of the scanner 23 (a beam of light) is fed into a gradient detector 25 and a zone detector 26'. The zone detector comprises a color analyzer 26 and a color comparator 30. The aforementioned boundary detail information is analyzed in the gradient detector 25 and the color information is analyzed in the zone detector 26'. A printout scanner 29 receives the boundary detail information on a gradient detector output line 27 and the decoded color information on a zone detector output line 31.

The input specimens are multicolor photographic prints and transparencies. The output print is a sheet of photosensitive material marked with suitable indicia to serve as a guide to assist an artist in creating an original rendition of the image portrayed on the input specimen.

In order that the following detailed description of the system 21 be best understood, it is important that the objectives and functions of the system be known. For this purpose a sample input specimen and a sample output print will be examined. Attention is directed to FIG. 2, which shows a reproduction of a sample input specimen 33, that specimen being a photograph of a still life comprised of a pear 34 on a plate 35, and to

FIG. 3 which shows a printed output guide 36 obtained by the operation of the system 21 on the input specimen 33. As illustrated, the input specimen 33 is what is commonly called a black and white image. It will be appreciated, however, that such an image is broadly multicolored although the colors vary only in value and there are no components of hue or saturation. Thus, as used in the following description and claims the term multicolored is meant in its broad sense as including variations in hue, saturation and value occurring either individually or in combination.

An examination of the photograph 33 reveals three distinct forms of information that would be useful to an artist attempting a rendering. First, there are sharp detail boundaries such as a boundary 37 between a dark right side 38 of the pear 34 and a lighter background 39. This particular boundary 37 is clearly noticed, because of the sharp difference in color value between the side 38 of the pear 34 and the background 39. Other, more subtle boundaries also exist. For example, a boundary 41 exists between the plate 35 and a surface 42 upon which the still life rests. While boundaries 41 of the latter type are less obvious on a casual observation of the photograph 33 they are nevertheless important to the painter. The boundary 37 is shown on the output print 36 by outline indicia comprising a plurality of light grey lines 37' and the boundary 41 is depicted in FIG. 3 by a plurality of light grey lines 41'. The lines 37' and 41' and the other detail boundary lines on the guide 36 that are not specifically noted are printed by a scanner (described below) and the scanning direction is vertical as seen in FIG. 3. Therefore detail boundaries that are vertical will show as single continuous lines such as large segments of the line 37' and those detail boundaries with a substantial horizontal component will be depicted by a plurality of short parallel lines such as 41'.

Another type of useful information relates to gradual transitions in color that occur within the sharply defined boundaries 41. These transitions are indicated on the guide 36 by zone indicia comprising short horizontal lines 47 and short vertical lines 48. The zone indicia 47, 48 identifies areas on the guide 36 that correspond to zones of substantially uniform color characteristics within the photograph 33. For example, horizontal lines 49 and vertical lines 51 outline in guide 36 an area 43' that corresponds geometrically to a bright highlight zone 43 in the pear shown in FIG. 2. Since transitions represented by the lines 47 and 48 are generally gradual and represent color variations less defined than actual detail boundaries portrayed by the photographs 33, they are not detected by the gradient detector 25.

The final type of information provided by the guide 36 relates to the specific paint color that should be applied to each area defined by the zone indicia lines 47, 48. This color information is conveyed by zone indicia 44 applied to all areas defined by lines 47, 48. For example, as shown in FIG. 3, the area 43' retains the paint color identification numeral 12 which instructs the artist to use in zone 43' a particular paint color arbitrarily identified by the numeral 12. Similarly, all other areas or zones in the printout guide 36 retain at least one numerical designation 44 representing a specific color of paint to be applied to that zone.

Referring now to FIGS. 4 and 5 there are shown mechanical (FIG. 4) and electrical (FIG. 5) diagrams of the system 21. A strip of 70 mm transparencies (not

shown) is placed in a film transport 55 in the input scanner 23 and advanced incrementally by an input stepping motor 57 while a wide roll of photosensitive material (not shown) is placed in an output paper transport 58 and advanced incrementally by an output stepping motor 59. The input motor 57 and the output motor 59 are responsive to signals delivered by a line 62' from a computer 63. A light beam 62 spanning the width of the transparency (not shown) and having been modulated by color variations therein is reflected by a mirror 60 to a scan position control 64. Included in the scan position control 64 is a rotatably mounted reciprocating mirror 65 that pivots on a shaft 66. Reflections 67 from optically aligned positions on mirror 65 are directed by a lens 68 to a mirror 72. At any given time the lens 68 transmits only a small portion of the broad beam 62 and that portion constantly changes as the mirror 65 reciprocates. Consequently, transmitted beam 69 represents an optical scan across the surface of the transparency at a rate determined by the reciprocating mirror 65. Since the mirror 65 rotates about a single axis 66, each scanning line is one dimensional and a scan of the entire surface of the transparency is accomplished by slight displacements thereof by the stepping motor 57 after completion of each line scan. Also, the generated scan is bi-directional rather than unidirectional as in a television receiver in which there is a rapid retrace. In the system 21, successive scans are in opposite directions as the mirror 65 rotates first clockwise and then counterclockwise.

After reflection by the mirror 72 the beam 69 impinges on a dividing mirror 73 with a resolution control aperture 74 therein. The aperture 74 is substantially smaller than the diameter of the beam 69. For example, in a preferred embodiment, the aperture 74 is approximately one tenth the diameter of the beam 69 and therefore 1/100 of the scanned area passes through the aperture to the gradient detector 25. The remainder of the beam 69 is reflected by the mirror 73 to the zone detector 26'. In the zone detector 26' the beam first enters a color analyzer 26 and strikes a dichroic beam splitter 75 that reflects the blue component 76 thereof to a photodetector 77. The beam splitter 75 passes the red and green components as a beam 78 to another dichroic beam splitter 79 that reflects the green component 82 into a photocell 83 and passes the red component 84 to a photocell 85.

As shown in FIG. 5 the gradient detector 25 is connected by the line 27 to an electro-optical modulator 86 that is part of the printout scanner 29. The zone detector 26', comprising the color analyzer 26 and a color comparator 30 is connected by the line 31 to the computer 63 within the printout scanner 29. A radiant energy projector 87 that comprises a laser 88 projects a beam of polarized light 89 into the modulator 86. A beam of light 92 that emerges from the modulator 86 has been modulated in response to signals received from the gradient detector 25 so that when a detail boundary in the input specimen 33 is sensed the modulator 86 passes light. At all other times, the beam 92 is extinguished. The beam 92 is directed by a plurality of mirrors 93, 94, 95 and 96 and then focused by a lens 97. Emerging from the lens 97 is a beam 98 that is focused and convergent with an output 102 from a second radiant energy source 99 to be described in detail below. The beam 98 and the output 102 are reflected by a pair of objective mirrors 103 and 104 and then fo-

cused by a lens 105. The beams 98 and 102 do not fully converge until they reach the output scanner 58, but to preserve clarity they are shown as converged into a single beam 106 emerging from the lens 105. The beam 106 is reflected from an output side 107 of the synchronizing mirror 65 forming an output beam 106'. The output beam 106' scans one dimensionally. The print-out guide 36 that is being produced in the output scanner 58 is incrementally moved by the stepping motor 59 as was the input transparency strip. Scanning of the output beam 106' is similar to the input scanning with sequential right to left and left to right scans coupled with an incremental vertical motion of the printout guide between each scan. Since the input beam 62 and the output beam 106' are both controlled by the mirror 65 and the motors 57 and 59 are activated simultaneously, spatial synchronization is achieved.

The beam 89 strikes a beam splitter 108 that passes the beam 89 substantially unaltered, but reflects a small portion 109 thereof (for example, 4 percent) through a plurality of mirrors 112, 113 and 114 to a collimator 115. A collimated supplementary beam 116 is formed that impinges on the output surface 107 of the synchronizing mirror 65. A beam 116' is reflected and scans a clock 117 that is further described below. The output of the clock 117 is a pulse train on a line 118 (FIG. 5) that is connected to both the computer 63 and an AND gate 119 that enables the zone detector 26' through a line 122. The pulse train is used by the computer 63 to determine the position of the beam 106' as described below. Another input 123 of the AND gate 119 is connected to the computer 63 by a line 124. The second radiant energy source 99 is modulated by the computer 63 and is connected thereto by a line 125. The second source 99 prints the numbers 45 and dividing lines 47 and 48 as described below.

Referring now to FIG. 6 there is shown the format used on a 70 millimeter transparency strip 132 that is made from the original input specimens 33. The image from the original input specimen 33 is photographed and appears on the strip 132. For example in FIG. 6, the portrait of a young woman 133 appears. Also included on the transparency strip 132 is information not originally on the input specimen 33. This information includes mailing label data 134 to identify the owner of the input sample 33, a color control patch 135 and other color information 136 that is used as explained below. On one side 137 of the transparency strip 132 is a series of fiducial marks 138. The instructions contained in the machine readable fiducial marks 138 control the direction of the scan, and program the scanner 23 to read either normal picture information, the mailing label 134 or the supplementary color control information 135 and 136. Since the size and shape of the output print 36 are controlled by indications on the transparency strip 132 and the output print 36 is produced from a roll of sensitized paper greater system flexibility is obtained. This is because the size and shape of the output print 36 can be changed with no alterations in the system 21. Furthermore, when system control is supplied by the fiducial marks 138 the entire system 21 is simplified as compared to a system in which the scanner 23 is controlled by computations such as scan counting made within the computer 63. The fiducial marks 138 are read by conventional techniques and the equipment used is not shown.

Referring next to FIG. 7 there is shown a diagram of a standardizer 142 that includes a camera 143, a plurality of corrective filters 144, 145 and 146 and an input support 147 with a cropping platten 148. The standardizer 142 also includes a comparator that will be described below. The corrective filters include a neutral density filter 144, a plus or minus red filter 145 and a plus or minus blue filter 146. The camera 143 is a reflex type and the viewing system will be described below. The camera 143, the input support 147 and a lamp support 149 are mounted on a rail 152 with sliding brackets 153, 154 and 155 respectively. The cropping platten 148 can be moved vertically or horizontally by a y-drive motor 156 and an x-drive motor 157 respectively and mounted on the cropping platten is the input specimen 33. The lamp support 149 carries a plurality of lamps 158 that illuminate the input specimen 33. The camera 143 is focused by moving the bracket 153 on the rail 152. Correct cropping is achieved by moving the mounts 154 and 155 on the rail to provide the proper magnification or reduction and actuating the x and y motors 157 and 156, respectively to position the input specimen 33 in the event that the image 34 thereon is off center. The standardizer 132 that is used with transparency input specimens 33 is similar except that the transparencies are illuminated from behind. Focusing and cropping procedures are similar.

Referring now to FIG. 8 there is shown a schematic diagram of a comparator 162 that is part of the viewing system of the camera 143. On the operator's control panel (not shown) are a comparator viewfinder 163, an object image viewing screen 164 and a reference viewing screen 165. In the comparator viewfinder 163 is an eyepiece 166, the viewing area of which is divided into two semi-circular segments 167 and 168. Shown in the area 167 is a small preselected portion 169 of an image 172 from the reference image viewing screen 165. A fiber optic light pipe 173 carries the image of the small portion 169 to the area 167. Shown in the area 168 is a small portion 174 of the image shown in the object viewing screen 164, that is the image shown on the input specimen 33. A movable probe 175 is adjusted to select the position of the small portion 174 and carry the image thereof to the area 168. In a preferred embodiment 21 the eyepiece 166 exhibits a magnification of approximately 10 power to simplify comparison of the areas 167 and 168. Below the viewing screens 164 and 165 are mirrors (not shown). The mirror below the screen 164 is a conventional movable mirror as found in reflex camera viewfinders that reflects the image to the viewing screen 164 but is automatically moved during exposure. The mirror below the screen 165 is permanently fixed and reflects the image 172 to the screen 165. Also on the viewing screen 164 are fiducial marks 176 to aid in the positioning and cropping of the input specimen 33. The image 172 on the reference viewing screen 165 is supplied by a transparency sheet 177 that is illuminated by a reference lamp 178 and focused by a set of condensing lenses 179 and objective lenses 182. It will be apparent that a sheet of prints with front illumination could be used to supply the reference image 172 if desired. A plurality of individual images 172 are contained on the transparency sheet 177 and selector motors 183 are used to position the desired image 172 between the lenses 179 and 182. The plurality of images 172 comprises photographic subjects of various facial colors and the image 172 selected for any indi-

vidual input specimen 33 that is a photograph of a person of the facial type corresponding most closely to the person shown on the input specimen. The light pipe 173 is disposed so that a medium skin tone of the reference image 172 is shown in the area 167. Likewise, the probe 175 is positioned so that a medium skin tone from the input specimen 33 is shown in the area 168. The reference image 172 is used for color comparison and correlation purposes as described below. However, variations in the color temperature of the lamp 178 caused by lamp aging or voltage variations will affect the color balance of the image 172. Therefore, a record of the condition of the lamp 178 is made by taking a sample of light through a fiber optics light pipe 184 that is focused on the transparency strip 132 to expose the color control patch 135 as shown in FIG. 6. In order to preserve clarity, the lenses and mirrors utilized in focusing the color control patch 135 are not shown. A plurality of small light bulbs near the shutter of the camera 143 that expose the color code patches 136 are not shown in order to preserve clarity. The conventional focusing system used for the mailing label 134 is also omitted.

Referring now to FIG. 9 there is shown a diagram of a preferred operator control panel 192 including the eyepiece 166, the object image viewing screen 164 and the reference viewing screen 165. In the lower left corner of the panel 192 is a selector switch 193 that is set to either transparency or print positions, depending upon the nature of the input specimen 33. A plurality of push buttons 194 are used to select the proper reference image 172. The buttons 194 also allow the operator to select which of the preselected palettes is most compatible with the background of the image on the input specimen 33. The color data blocks 136 record which palettes are selected for the face, hair and background. Two position control switches 195 and 196 control the motors 156 and 157 to center the input specimen, and a magnification switch 197 controls the position of the input support 147. A focus switch 198 controls the focus of the camera 143. The three filters 144, 145 and 146 shown in FIG. 7 are controlled by the switches 202, 203 and 204 respectively. The switches 193, 195-198, 202-204 are positioned between indicator lights 205 that show when the limit of the range of the control function for each switch has been reached. Disposed below the viewing screens 164 and 165 is a film footage indicator 206 and a film end indicator 207 to show when the end of the film is reached. Above the switches 194 is an expose switch 208 that is actuated to make the exposure of the input specimen 33 after the proper cropping and corrective adjustments are completed.

Referring now to FIG. 10, there is shown a perspective view of the scan position control 64. The two-sided mirror 65 is mounted on the shaft 66 that is supported by a frame 212. Two loudspeakers 213 are also mounted on the frame 212. A line 214 connects the speakers 213 to a scan oscillator 211. Mounted on the shaft 66 and perpendicular thereto is a lever arm 215 with push rods 216 connected to each end thereof. The push rods 216 are also connected to small discs 217 that are secured to the insides of the cones 218 of the speakers 213. The speakers 213 are operated in phase so that the push rods 216 alternately push and pull the ends of the lever arm 215 and thereby rotatably reciprocate the shaft 66. The two-sided mirror 65 therefore

rotatably reciprocates and the magnitude and frequency of the motion thereof is controlled by the scan oscillator 211. The beam 62 is reflected by an input face 213 as shown in FIG. 4 and the beams 106 and 116 are reflected by the output face 107 as shown in FIG. 4.

Referring next to FIG. 11 there is shown a diagram of an input 232 of the gradient detector 25 comprising the resolution aperture 74 shown in FIG. 4. Two baffles 233 and 234 divide the aperture 74 into four quadrants 235, 236, 237 and 238. The light that enters the quadrants 235-238 is carried by light pipes (not shown) to four photodetectors 242, 243, 244 and 245 that are connected to lines 246, 247, 248 and 249 respectively. The photodetectors are paired diametrically so that the difference in light intensity measured by the detectors 242 and 244 indicates a detail boundary therebetween. In FIG. 11 this boundary is indicated schematically by a vector 252 perpendicular thereto, the length of the vector representing the difference in magnitudes measured by the detectors 242 and 244. Likewise a vector 254 represents any boundary detected by the detectors 243 and 245. Any boundary within the aperture 74 regardless of orientation is detected by its orthogonal components as shown by vectors 252 and 253.

Referring next to FIG. 12 there is shown a block diagram of the electronic circuitry 255 of the gradient detector 25. The outputs of the photodetectors 242-245 are amplified by four log amplifiers 256, 257, 258 and 259 respectively. An output of the log amplifier 256 appears on a line 262 and an output of the log amplifier 257 appears on a line 263. The difference in signal level on the lines 262 and 263 is dependent on the length of the vector 252. A differential amplifier 264 determines the length of the vector 252 from the signals on the lines 262 and 263. The log amplifiers 256 and 257 are used between the detectors 242 and 244 and the differential amplifier 264 because any change in the input of a log amplifier is reflected in the output regardless of the base level of the input signal. Therefore, the gradient detector 25 is sensitive to detail boundaries in both light and dark areas in the transparency strip 132. The signal representing the length of the vector 252 as determined by the differential amplifier 264 is split on a line 265 and fed to a multiplier 266. An output of the multiplier 266 on a line 267 represents the length of the vector 252 squared. A complimentary circuit 268 provides the squared value of the length of the vector 253 on a line 269. A summing amplifier 272 adds the signals on the lines 267 and 269 and therefore determines the square of the length of the vector sum of the vectors 252 and 253. The vector sum of the vectors 252 and 253 is dependent on the magnitude of a detail boundary within the aperture 74 and is independent of the orientation of that boundary. The signal representing the square of the magnitude of the boundary is available on a line 273 and is delivered to a Schmidt trigger 274. The Schmidt trigger 274 is a threshold detector and is set to the sensitivity that is desired in the gradient detector 25. An output of the Schmidt trigger 274 is available on the line 27 and is delivered thereby to the electro-optical modulator 86 as shown in the FIG. 4. A more complete discussion of gradient detectors can be found in the applicant's copending application Ser. No. 71,816 filed Sept. 14, 1970, now U.S. Pat. No. 3,696,249.

Mathematically color selection in the zone detector 26' proceeds as follows. Preselected color domains to represent various tonalities present in the photograph 33 to be rendered are registered in the analyzer 30. The color domains are initially established in a three-dimensional polar coordinate colorimetric system of the type illustrated in FIG. 13. In that system, the value component V of a given color (also known as lightness or brightness of the color) is measured along on axis $x-x$, a component of saturation θ (also known as chroma) is measured radially from and perpendicular to the axis, $x-x$, and components of hue are measured by angle θ . A preferred approach to the establishment of appropriate color domains is diagrammatically illustrated in FIG. 14 which is a graph plotting color component values of hue and saturation in the colorimetric system shown in FIG. 13 with the relative positions of the primary colors red, blue and green indicated. Strategically located coordinate positions represented in FIG. 14 by circular points P are selected such that lines 2 defined by points equally spaced between adjacent points P define boundaries for the identified zones. The function and selection of the color coordinate positions P is described in detail in the applicant's pending application. In a specific case involving the portrait of a photographic subject with light skin and blond hair, zone or color domain A might encompass all the analyzed colors of the subject's hair while zone or color domain B might encompass all the analyzed flesh tones present in the subject's face. Similarly, color domain C might encompass all the analyzed pinkish colors present in the subject's lips while color domain D would encompass those neutral gray tones present in the photograph. Finally, color domains E, F, G and H would encompass various background colors present in the photograph.

An oil paint rendering of the photograph 33 clearly requires the use of a plurality of distinctly colored paints corresponding to the color domains A-H depicted in FIG. 14. However, in plotting the points P on the two-dimensional graph shown in FIG. 14, the value components of the measured colors were ignored. To properly quantize the three-dimensional color space illustrated in FIG. 13 value components must be considered. A three-dimensional system such as that shown in FIG. 15 is utilized in the preferred embodiment 21. Considerations relevant to selections of the color zones are fully discussed in the copending applicant's U. S. application Ser. No. 128,418 filed Mar. 26, 1971. The color zones thus obtained are then transformed by conventional mathematical operations into coordinates that are compatible with the tristimulus component values of the various colors present in the photograph 33 as measured by the zone detector 26'. Descriptions of such transformations can be found, for example, in "Color Science" (Gunter Wyszecki and W. S. Stiles) published by John Wiley & Sons, Inc. The domains shown in FIGS. 14 and 15 are defined in terms of points P, and each domain represents a color of paint, so the function of the zone detector 26' is to calculate the closest point P to the color being scrutinized, thereby determining which color of paint will be used. The calculation of the nearest point P is three-dimensional, that is, the value component of the scrutinized color need not equal one of the seven quantized value levels in FIG. 15.

Each of the several reference images 172 is associated with a separate palette of colors, hence each image is associated with a separate set of points P. The computer 63 is responsive to the color control blocks 136 and automatically selects the proper set of points P to be used with each transparency 132.

Referring next to FIG. 16 there is shown a diagram of the electronics 282 of the color analyzer 26 and the color comparator 30. The beams 76, 82 and 84 that represent the intensities of the blue, green and red components respectively of an individual point on the transparency strip 132 are measured by the photodetectors 77, 83 and 85. A signal of a level representing the blue component as sensed by the photodetector 77 is fed to a log amplifier 283 by a line 284. The log amplifier 283 is used since the response of a log amplifier closely resembles the color response of a human eye. A resistor 280 carries the signal to a driver amplifier 281 and then a line 285 carries the output of the log amplifier 283 to a summing junction 286 that is responsive to an enabling signal from the AND gate 123, delivered by the line 122. An output of the summing junction 286 that is available only when the enabling signal is present is carried by a line 287 to a sample and hold amplifier 288 and stored therein. The signal level information in the sample and hold amplifier 288 is therefore available continually until the summing junction 286 is again enabled by the AND gate 123. The information in the sample and hold amplifier 288 is carried to the comparator 30 by the line 28b. A green detector circuit 289 is connected to the photodetector 83 and delivers the information regarding the level of the green component on the line 28g and a red detector circuit 292 delivers information concerning the level of the red component on the line 28r. The AND gate 123 is connected by a line 118 to a clock 117 as described below, and to the computer 63 by the line 124. The clock 117 provides a pulse train output, each pulse denoting a specific predetermined position of the scanning beams 62 and 106' as described below. The clock 117 produces 100 pulses during each scan line, or 200 during each scanning cycle to provide an accurate indication of the position of the scanning beams 62 and 106'. The clock 117 therefore controls the precise time at which the zone detector 26' is enabled, and the computer 63, through the line 124, enables the AND gate 123 to respond to particular pulses from the clock to provide an interlace pattern.

Still referring to FIG. 16, attention is directed to the computer 63 which reads from the input transparency (FIG. 6) the control patch 135 and the color control blocks 136 when so instructed by the fiducial marks 138. In response to the information contained in the color control blocks 136 the computer 63 instructs a memory 275 through a line 31' to select the proper palettes. The information stored in the memory 275 for each palette comprises a plurality of sets of coordinate positions of the points P representing the colors available on the selected palette. Each point P is represented by a set of coordinate positions. If the condition of the lamp 138, as indicated by the control patch 135, requires an adjustment in the coordinate positions of the points, the adjustment is made within the memory 275 in response to additional signals received on the line 31'. The selected and adjusted coordinate positions are placed in an auxiliary memory 276 through a line 275'. Accompanying each set of coordinate posi-

tions is a numerical designation corresponding to the number of the paint associated with that particular point P. From the auxiliary memory 276 the sets of coordinates are placed sequentially in a digital to analog converter and buffer 277. The following set is passed to the converter and buffer 277 in response to signals from a sample clock 278 that is connected to the auxiliary memory 276. A line 279 carries the numerical designation representing the set of coordinate positions in the buffer 277 to a register 293. The designation represented on the line 279 is accepted by the register 293 only if a signal is received by the register on a line 294.

A line 28b' carries the analog value of the blue coordinate position of the point P currently in the buffer 277 therefrom to a differential amplifier 295. The output of the differential amplifier, representing the difference between the measured value on the line 28b and the sample value on line 28b' is fed to a multiplier 296b and squared. Similar information concerning to the green and red components respectively is available at the outputs of two additional multipliers 296g and 296r. A summing amplifier 297 adds the signals from the multipliers 296b, 296g and 296r, thereby calculating a value that may be thought of as the squared vector distance in three dimensional space between the point P and the color being analyzed. The output of the summing amplifier 297 is carried by a line 297' to a comparator 298 and a summing junction 299. The summing junction 299 passes the signal to a sample and hold amplifier 300 only in response to a signal on the line 294. The comparator 298 compares the signal on the line 297' to the signal level stored in the sample and hold amplifier 300. The difference therebetween is fed to a Schmidt trigger 301. If the signal on the line 297' is greater than the signal level in the sample and hold amplifier 300 there is no response from the Schmidt trigger 301. However, if the signal level on the line 297' is lower than the signal level stored in the amplifier 300 the Schmidt trigger is activated, but the output thereof reaches the line 294 only after passing through a delay circuit 301'. When the signal reaches the line 294 the register 293 is activated and receives the numerical designation on line 279, and the summing junction 299 passes the signal level on the line 297 to the sample and hold amplifier 300.

Since the signal level on line 297' represents the squared value of the vector distance between the point P currently represented in the buffer 277 and the color being analyzed, a lower signal level on the line than in the sample and hold amplifier 300 indicates that the current point P is closer to the actual color than what has been measured before. As stated previously, simultaneously with the recording of the distance between a point P and the color being analyzed, the numerical designation representing that point P is recorded in the register 293. Therefore, at all times the register 293 indicates the numerical designation of the paint closest to the color being analyzed of those paints that have been compared. After the comparison process is completed another pulse is received from the sample clock 278 and the auxiliary memory 276 supplies another set of coordinates to the buffer 277 and the process is repeated. When all the points P representing the paint colors in the selected palettes have been compared the numerical designation present in the register 293 therefore indicates the paint best suited for the color just analyzed, and the numerical designation is passed to the

computer 63 on the line 31. When the next zone is to be sampled, a pulse on the line 124 both enables the AND gate 119 to cause a sample to be taken by the color analyzer 26 and instructs the auxiliary memory 276 to again sequentially supply the coordinates of each point P to the buffer 277 in response to the clock 278.

Referring next to FIGS. 17, 18 and 19 there is shown in detail the second radiant energy source 99 that is connected to an interlace circuit within the computer 63 by the line 125. The interlace circuit modulates the second radiant energy source 99 for printing at the appropriate time during the scanning cycle. A memory within the interlace circuit records the information obtained from the zone detector 26' by the cable 31 until printing. In the rear of the second radiant source 99 is a support 304 that holds 16 flashtubes 305-320 in place and is shown in detail in FIG. 18. At the front of the second radiant source 99 is an aperture mask 321 that supports a plurality of lenses 322 and defines 16 apertures 305a-320a, each aperture corresponding with one flashtube 305-320. The flashtubes 305-320 are operated selectively by the computer 63 and produce an output in the form of a character stroke matrix. Activation of the proper combination of flashtubes 307-320 will project a beam 102 in the form of any number from 00 thru 99. For example, the number 88 is formed by activation of all flashtubes 307-320, and 11 is formed by the activation of only the flashtubes 308, 311, 315 and 316. The flashtubes 305 and 306, when activated, form the vertical lines 48 and the horizontal lines 47, as shown in FIG. 3, respectively.

Referring now to FIG. 20 there is shown the color clock 117. Fifty gate openings 332 in a front face 333 are scanned by the beam 116'. The intermittent beam 116'' that passes through the gates 332 is focused on a photomultiplier 335 by two lenses 334. Therefore, during each scan the photomultiplier 335 detects 50 pulses that determine the position of the scanning beams 62 and 106' without reliance on timing circuits. A line 336 splits the output of the photomultiplier 335, delivering one half thereof to an inverter 337 and another half thereof to a differentiator 338. The output of the inverter is delivered by a line 339 to another differentiator 342. The output of the differentiator 338 is delivered by a line 343 to a clipping diode 344 and then by a line 345 to a summing junction 346. The output from the differentiator 342 is delivered by a line 347 to another clipping diode 348 and then by a line 349 to the summing junction 346. The output of the summing junction 346 is available on the output line 118. The operation of the clock 117 may be better understood with reference to FIG. 21 which shows the waveforms at various points within the circuit. An uppermost waveform 352 shows the voltage on the line 336 which is a square wave that is at peak value when the beam 116'' is passing through an opening 332 and is at zero value when no light strikes the photomultiplier 335. A second waveform 353 shows voltage on the line 339, which is an inversion of the waveform 352. Two other waveforms 354 and 355 show the outputs of the differentiators 338 and 342 respectively. Two waveforms 356 and 357 show the voltages on the lines 345 and 349 respectively. These waveforms 356 and 357 are the clipped, or positive values of the voltages on the lines 343 and 347. An output waveform 358 shows the voltage on the line 118 which is the sum of the voltages on

the lines 345 and 349. The voltage on the line 118 is a pulse train with 100 pulses 359 during each scan of the scanning beams 62, 106' and 116' or, 200 pulses during each scanning cycle.

Referring now to FIG. 22 there is shown a diagram of the pattern used by the zone detector 26' in scanning, and by the second radiant energy source 99 in printing. The area 362 is composed of a plurality of small parallelograms 363 and represents a small area of the transparency strip 132. Scanning is horizontal as viewed in FIG. 22. Individual scan lines are not shown in FIG. 22 to preserve clarity. In the system 21, the distances A and B are each 2/10 of an inch and each covers 10 scans, or five scanning cycles. Similarly, portions of approximately five scanning cycles are covered by each parallelogram 363. The pattern is formed as follows. Assume that the first scan line proceeds from left to right as shown in FIG. 22 and passes through the center of the parallelograms 363 labelled 1, and passes below center, if through the other parallelogram 363 at all. The position of scanning beam 62 is continually calculated by the computer 63 in response to the pulses 359 on the line 118. The transparency strip 132 and the printout guide 36 are each 100 parallelograms 363 wide and the clock produces 100 pulses per scan. Therefore, whenever the beam 62 is horizontally centered in a parallelogram 363 a pulse appears on the beam 118. When the scanning beam 62 is in the center of any of the parallelograms 363 labelled 1 the computer 63 enables the zone detector 26' through the AND gate 119. The color components are measured as described above, and the number of the paint chosen to be used is stored within the computer 63. This procedure is followed for each of parallelograms 363 labelled No. 1. At the end of the first scan, there is a vertical displacement by the motor 57 and the second scan begins, proceeding from the right to the left. The second scan passes through the center of the parallelograms 363 numbered 2, and when the scanning beam 62 is in the center of any of the parallelograms numbered 2 the computer 63 enables the zone detector 26'. In addition, when the scanning beam 62 is directly above the center of the parallelograms 363 numbered 1, the computer 63 modulates the second radiant energy source 99 through the line 125 to print the color number selected for the parallelogram 363 numbered 1. To both simplify printout and produce on the output guide 36 color information that can be readily observed, the computer 63 energizes flashtubes 307-320 only if both flashtubes 305 and 306 are flashed. Therefore, numbers 45 appear only in the upper left corners of the areas 43' and 46' as shown in FIG. 3. The second radiant energy source 99 is slightly off set so that even though printing is one scan late, the color number 45 is properly centered within the parallelogram 363. Similarly, during the third scan the numbers chosen for the parallelograms 363 numbered 2 are printed, and the parallelograms numbered 3 are sampled. On the tenth scan the parallelograms 363 labeled 10 are sampled, and on the eleventh scan the parallelograms labelled 1' are sampled, and so on until the entire transparency strip 132 has been scanned.

Operation of the system 21 begins with receipt of an input specimen 33 that must be recorded on the transparency strip 132 shown in FIG. 6. An operator fixes the input specimen 33 to the input platten 148. Another operator viewing the panel 192 then sees the

image 34 of the specimen 33 in the viewing screen 164. The image 34 is positioned, cropped and focused by the operator with the switches 195, 196, 197 and 198. Next, if the image 34 is a portrait of a person, the operator selects a reference image 177 with the switches 194. The reference image 177 that is chosen is the one nearest to the subject person's facial type. The proper palette selections for the chosen facial type are automatically recorded on the color code blocks 136 according to the reference image 177 that appears in the screen 165 during exposure. The switches 194 are also used to select other palettes for the background of the input image 34 and this choice is recorded in the color code blocks 136 at exposure. The probe 175 is then adjusted to cover a medium skin tone on the image 34 and the operator turns his attention to the eyepiece 166. The neutral density filter 202 and the plus or minus blue and plus or minus red filters 203 and 204 are then adjusted until the dividing line between the areas 167 and 168 disappears, indicating that the color balance of the input image 34, as adjusted by the filters 202, 203 and 204, matches the reference image 177. Finally, the expose button 208 is pressed and an exposure is made recording the input image 34 on the transparency strip 132 with the mailing label 134, the color control patch 135 and the color control blocks 136. The next input specimen 33 is photographed in the same manner. Input specimens 33 of the same type, for example, 35 mm transparencies are grouped together to minimize the time required for photographing. Similar size input specimens 33 eliminate or substantially reduce the time required for framing and cropping.

The remaining operation of the system 21 is best explained in two parts. The first part includes the operation of the gradient detector 25 and the first radiant energy source 88 and the components associated therewith. The transparency strip 132 is placed in the framer 55 and is illuminated from behind and, as the two-sided mirror 65 reciprocates, light emanating from different portions of the surface of the transparency strip is focused as the beam 69 on the dividing mirror 73 as described above. Scanning is vertical on the transparency strip 132 in the orientation shown in FIG. 6. The fiducial marks 138 on the transparency strip 132 are detected by conventional means, and the computer 63 prepares for different functions in response to the marks. For example, the marks 138 may direct the computer 63 to read and analyze the color control patch 135 and color data blocks 136, or cause the laser 88 operating in a facsimile mode to print the information contained in the address label 134. Normally however, the instruction contained in fiducial marks 138 is to scan from right to left or scan from left to right. The stepping motors 57 and 59 are also responsive to the fiducial marks 138 so both the input framer 55 and the output scanner 58 are stepped simultaneously. As the transparency strip 132 is scanned, the light emanating from the different areas thereof impinges on the splitting mirror 73 and only the light from a very small area thereof passes through the aperture 74 to the gradient detector 25. The gradient detector 25 functions as described previously to provide an output on the line 27 only if a detail boundary is within the area being passed by the aperture 74. In response to an output on the line 27 the electro-optical modulator 86 passes the beam light 89. Therefore, the beam 92 exists only when a detail boundary is sensed by the gradient detector 25. The

beam 92 is focused as described above and reflected by the output face 107 of the mirror 65 to the printout scanner 58 as the beam 106'. Since response time in the detector 25 is small, and the positions of the input scanning beam 62 and the output scanning beam 106' are both controlled by the mirror 65 no further synchronization therebetween is required. The output prints 36 as shown in FIG. 3 are printed on a continuous roll of sensitized material and the direction of scanning as shown in FIG. 3 is vertical. Therefore, the marks 37' and 41' exposed by the output from the laser 88 show as vertical lines.

During zone detection in the embodiment 21 the transparency strip 132 is scanned, and the light from various portions thereof is projected as the beam 69 to the mirror 73. As described previously, the color analyzer measures the red, green and blue components of the beam 69 when enabled by the AND gate 119. While the gradient detection and printout were substantially instantaneous, such is not the case with the zone detection. The color components sensed by the analyzer 26 are conveyed by the line 28 to the comparator 30. The comparison and final selections of one of the available colors to represent the zone being scanned is time consuming with respect to the scanning speed. Simultaneous printout is impossible if scanning speed is to be at a reasonably high level. Consequently, the scanning pattern shown in FIG. 22 is used. That is, during the first scan, each of the parallelograms 363 labelled No. 1 is sampled and the number of the color chosen therefor is stored within the memory of the computer 63. In the preferred embodiment 21 there are 10 parallelograms 363 labelled 1 spanning the width of the transparency strip 132. Therefore, there are 100 parallelograms 363 spanning the transparency strip 132. So at the end of the first scan the memory has recorded 10 numbers corresponding to colors. The second scan passes through the center of the parallelograms 363 numbered 2 and the analyzer 26 samples the parallelograms numbered 2 on the second scan. Also on the second scan, when the beam is directly above a parallelogram 363 numbered 1, the color information stored within the memory concerning that particular parallelogram is printed, if a print is to be made. The second radiant energy source 99 is slightly off set so that the printing appears in the center of parallelogram 363 labelled 1. As mentioned previously, the horizontal lines 47 and the vertical lines 48 that define the color zones 43' are only printed if they represent a true zone boundary, that is if they separate different colors. The calculation to determine whether or not to print the lines 47 and 48 is made by conventional techniques within the computer 63. Similarly, as mentioned with respect to FIG. 3, the zone identifying numbers 45 are printed only in upper left hand corners of zones 43' as viewed in FIG. 3. That is, the numbers 45 are printed only if both the horizontal and vertical lines 47 and 48 are printed. Conventional techniques are used to enable the number printing flashtubes 307-320 only if the flashtubes 305 and 306 are both activated.

In the preferred embodiment 21 the printout guides 36 are processed continuously in a roll and then are separated and laminated to backing boards. The palette selection information is imprinted on a border, and an operator selects the proper palette. The complete set is packaged and mailed according to the mailing label 134.

Referring to FIG. 23 there is shown a sample palette 371 typical of those that are supplied with the complete ensemble. A brush 372 and a plurality of different colored paints in vials 373, 374, 375, etc. are included. Each vial 373, 374, etc. bears a numerical designation 373a, 374a, etc. denoting the color of paint therein. The arbitrarily selected numerical designations 373a, etc. correspond to the identifying indicia 44 shown on printout guide 36 in FIG. 3.

The preferred techniques during the creation of a rendition with the present invention are similar to those used by an artist when painting with oil paints on a blank canvas. For example, and as previously noted, the region 43' on printout guide 36 (FIG. 3) is bounded by a plurality of rectilinear line segments 49 and 51. Clearly the corresponding region 43 on the pear 34 in FIG. 2 is not bounded by only straight lines and right angles. Therefore, paint is applied to the region 43' as generally indicated by the rectilinear lines 49 and 51, but the artist smooths the border by using curved brush strokes where necessary. In addition, as appropriately colored paints are applied to surrounding zones, such as 46', different color paints are blended at their juncture provided no detail boundary 37' or 41' appears therebetween. However and as previously mentioned, the paints applied on opposite sides of boundaries defined by boundary indicia 37' and 41' are not blended since these represent boundaries between distinctly colored areas existing, for example, between different objects. Thus, the rectilinear lines 49 and 51, in conjunction with the numerical designations 44, inform the painter which paint 373, 374 or etc. to use in general areas of the painting while the boundary indicia 37' and 41' define distinct objects therein. The proper use of both the zone indicia 49 and 51 and the detail boundary lines 37' and 41' results in a more professional looking rendition than was possible with prior craft kits of this type.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. Although for reasons of clarity the description has been specifically directed to oil painting applications, it will be obvious that the disclosed system would be useful for other craft endeavors such as needlework, watercoloring, mosaic creation etc. In addition, the broad concepts and techniques disclosed can be used in other seemingly diverse fields such as object recognition for map making purposes, classification of vegetation and minerals in aerial photographs, determination of water depths, etc. Such applications are considered within the scope of the appended claims. Further, it is obvious that the colors sensed need not be restricted to the visible part of the spectrum and that, for example, infrared sensors could be used to expand the dimensionality of the "color" analyses. In this regard, it should be understood that the broader term radiation spectrum can be substituted for the term color as used in the foregoing description. It is to be understood, therefore, that the invention can be practiced otherwise than as specifically described.

What is claimed is:

1. A system for analyzing multi-colored scenes and comprising:

- a. framing means for locating a scene to be analyzed;
- b. optical scanning means for scanning the scene to produce an optical output modulated by the image detail therein;

- c. gradient detector means receiving said optical output and responsive to image detail boundaries in the scene;
- d. color analyzer means receiving said optical output and responsive thereto to locate in the scene individual zones having predetermined color characteristics; and
- e. resolution control means for rendering said gradient detector responsive to image detail in scanned sample scene areas substantially smaller than the scanned sample scene areas retaining image detail to which said color analyzer means responds.

2. A system according to claim 1 wherein said resolution control means comprises optical divider means for separating said optical output into a gradient optical output for said gradient detector means and a zone optical output for said color analyzer means.

3. A system according to claim 1 including an interlace means for intermittently enabling said color analyzer means so that successively located ones of said individual zones are distributed in the scene in an interlace pattern.

4. A system for analyzing multi-colored scenes and comprising:

- a. framing means for locating a scene to be analyzed;
- b. optical scanning means for scanning the scene to produce an optical output modulated by the image detail therein;
- c. gradient detector means receiving said optical output and responsive to image detail boundaries in the scene, said gradient detector means comprising gradient detector output means for producing a gradient output signal indicating the location of said detail boundaries in the scene; and
- d. color analyzer means receiving said optical output and responsive thereto to locate in the scene individual zones having predetermined color characteristics, said color analyzer means comprising zone detection output means for producing a zone output signal indicating the location of said zones in the scene and color output means for producing a zone color output signal identifying the color characteristics present in each of said zones, and wherein said color output means comprises color comparator means for selecting from a predetermined finite set of color characteristics a particular color characteristic having a predetermined relationship with each of the analyzed color characteristics present in said zones, and said zone color output signal identifies said particular color characteristic selected for each zone.

5. A system according to claim 4 including printout means for producing a diagram of said boundaries and zones represented by said gradient and zone output signals and indicia in each of said diagram zones representing the particular said color characteristic associated therewith and identified by said zone color output signal.

6. A system according to claim 5 wherein said printout means comprises scanning means having radiant energy projection means for selectively exposing photosensitive material.

7. A system according to claim 6 wherein said projection means comprises a first radiant energy source means and first modulation means therefor and a second radiant energy source means and a second modulation means therefor.

8. A system according to claim 7 wherein said printout scanning means further comprises scanner control means for producing a relative scanning movement between said radiant energy outputs of said first and second modulation means and said photosensitive material, and including synchronizing means for synchronizing said scanning movement of said radiant energy outputs across said material with said analyzer scanning means.

9. A system according to claim 8 wherein said optical scanning means comprises resolution control means for rendering said gradient detector responsive to image detail in scanned sample scene areas substantially smaller than the scanned sample scene areas retaining image detail to which said color analyzer means responds.

10. A system according to claim 9 including printout control means for continuously modulating the energy output of said first modulation means in response to said gradient output signal, and for intermittently modulating the energy output of said second modulation means in response to said zone and color output signals.

11. A system according to claim 10 wherein said printout control means comprises printout delay means for providing a predetermined time delay between a given enablement of said color analyzer means and response of said second modulation means to the zone and color signals representing image detail information derived thereby; said predetermined time delay being controlled by said synchronizing means so as to produce a printout of color indicia at a time when said radiant energy output of said second modulation means is directed by said scanning means onto an area of said photosensitive material corresponding geometrically to the area of said scene being scanned at the time said given enablement of said zone detection means occurred.

12. A system according to claim 11 wherein said synchronizing means comprises a rotatably mounted mirror and drive means therefor, one surface of said mirror being disposed to reflect said optical output and the opposite surface of said mirror being disposed to reflect the output from said radiant energy projection means.

13. A system for analyzing multi-colored scenes and comprising:

- a. framing means for locating a scene to be analyzed;
- b. optical scanning means for scanning the scene to produce an optical output modulated by the image detail therein;
- c. gradient detector means receiving said optical output and responsive to image detail boundaries in the scene, said gradient detector means comprising gradient detector output means for producing a gradient output signal indicating the location of said detail boundaries in the scene;
- d. color analyzer means receiving said optical output and responsive thereto to locate in the scene individual zones having predetermined color characteristics, said color analyzer means comprising zone detection output means for producing a zone output signal indicating the location of said zones in the scene; and
- e. recording means for recording the information retained by said gradient and said zone output signals, said recording means comprising printout means for producing a diagram of said boundaries

and zones represented by said gradient and zone output signals.

14. A system according to claim 13 wherein said printout means comprises scanning means having radiant energy projection means for selectively exposing photosensitive material.

15. A system according to claim 14 including synchronizing means for synchronizing said optical scanning means and said printout scanning means.

16. A system according to claim 15 wherein said projection means comprises a first radiant energy source means and first modulation means therefor and a second radiant energy source means and a second modulation means therefor, said first modulation means being controlled by said gradient output signal and said second modulation means being controlled by said zone output signal.

17. A system according to claim 16 wherein said first radiant energy source means comprises a polarized light source and said first modulation means comprises an electro-optical modulator.

18. A system according to claim 16 wherein said synchronizing means comprises a rotatably mounted mirror and drive means therefor, one surface of said mirror being disposed to reflect said optical output and the opposite surface of said mirror being disposed to reflect the output from said radiant energy projection means.

19. A system according to claim 18 wherein said first radiant energy source means comprises a splitter means providing a primary input to said first modulation means and a supplementary output directed onto a surface of said rotatably mounted mirror and including clock means disposed to receive said supplementary output after reflection from said mirror.

20. A system according to claim 19 wherein said clock means comprises a gating means responsive to said supplementary output to produce a timing pulse train synchronized with said scanning means.

21. A system according to claim 19 wherein said second radiant energy source means comprises a plurality of flash tubes arranged in a pattern and selectively energized by said zone output signal to provide different optical outputs.

22. A system for analyzing multi-colored scenes and comprising optical scanning means for scanning the scene to produce an optical output modulated by the image detail therein; radiation spectral analyzer means receiving said optical output and responsive thereto to locate in the scene individual zones having predeter-

mined spectral characteristics, said spectral analyzer means comprising spectral output means including comparator means for selecting from a predetermined finite set of spectral characteristics a particular characteristic having a predetermined relationship with each of the analyzed spectral characteristics present in said zones and further including characteristic output means for producing a characteristic signal that identifies said particular spectral characteristic selected for each zone, and said spectral analyzer means further comprises zone detection output means for producing a zone output signal indicating the locations of said zones in the scene.

23. A system according to claim 22 including printout scanning means for producing a diagram of said zones represented by said zone output signals and indicia in each of said diagram zones representing the particular said spectral characteristic therewith and identified by said characteristic output signal.

24. A system according to claim 23 wherein said printout scanning means comprises radiant energy projection means for selectively exposing photosensitive material and modulation means for modulating said projection means in response to said zone and characteristic output signals.

25. A system according to claim 24 including synchronizing means for synchronizing said scanning means and said printout scanning means.

26. A system according to claim 25 including an interlace means for intermittently enabling said spectral analyzer means so that successively located ones of said individual zones are distributed in the scene in an interlace pattern.

27. A system according to claim 26 wherein said printout means comprises printout delay means for providing a predetermined time delay between a given embodiment of said zone detection means and response of said modulation means to the zone and characteristic signals representing image detail information derived thereby; said predetermined time delay being controlled by said synchronizing means so as to produce printout of characteristic indicia at a time when said radiant energy output of said modulation means is directed by said scanning means onto an area of said photosensitive material corresponding geometrically to the area of said scene being scanned at the time said given enablement of said zone detection means occurred.

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