of three-dimensional as well as two-dimensional objects; it computes the FFT both with single and with double precision; it makes it possible to simplify the obtaining of optical filters, such as matched, optimum, holographic, combinaation filters and the translator filter, which are used in the mathematical model of a recognition system,[2] the calculation of which is based on computing the spectra of objects.

Thus, the use of the PL/1 scientific subprogram package for calculating the spectra of objects facilitates solving of filtering and image recognition problems.

1. B. F. Fedorov and R. I. El'man, Opt. Mekh. Promst. No. 4, 21 (1972) [Sov. J. Opt. Technol. 39, 205 (1972)].
2. B. F. Fedorov and R. I. El'man, Tsifrovaya golografiya (Digital Holography), Nauka Press, 1977.

Obtaining a portrait of a person by the integral photography method

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A procedure is described for obtaining lens-array three-dimensional human portraits by the integral photography method.

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It is known that the integral photography method makes it possible to obtain color three-dimensional images of various objects, including, luminous, living, moving, etc. We have developed a modification of this method[1] that makes it possible to obtain three-dimensional images of such objects at different scales with excellent stereoscopic properties, a large depth of field, high resolution and other characteristics that exceed the same characteristics that are achievable by other methods of lens-array three-dimensional photography.

As a result of our studies we have found methods of designing schemes for taking and reconstructing a lens-array integral image that make it possible to determine the optimum relationship between the characteristics of the object, the parameters of the equipment used and the properties of the three-dimensional image.[2] We found that in principle we can obtain integral images of acceptable quality (an angular resolution of $\sim 2.5'$) of practically all subjects used in photography.[3] In order to demonstrate the possibilities of the method we have apparently obtained the first series of color integral portraits of a human being.

For the photographs we used a prototype of a raster camera, consisting of an objective lens (600-mm focal length, a square aperture diaphragm that is 120 mm on a side) and a raster photographing system containing an array spherical lens elements, fabricated at VNIIOFI (the array spacing is 0.4 mm, the diameter of the lens elements is 0.29 mm, their focal length is 4.0 mm, and the overall dimensions of the array plate are 240×280 mm), and a film emulsion (TsO-T-90L color reversal film with a sensitivity of 90 GOST units, sensitized to the spectrum of an incandescent lamp). A special cassette with a pneumatic hold-down mechanism was used to keep the film plane flat.

The array photographing system was focused onto a plane located 75 mm in front of the array since, according to our data, this focusing distance for this type of array provides for a good-quality reconstruction of the integral image. This plane was conjugate with the focusing plane of the objective lens, located in object space.

The object was illuminated with standard incandescent lamps. The exposure time was 0.1–0.5 sec, which corresponds to the usual conditions of studio photography with this same object illumination level. The film was processed in accordance with the S-9165 regime, recommended for ORVO-KhROM film. The processed and dried film was assembled into a unit with the lens array, and their relative position was adjusted by means of the moire pattern.[4] A color optical model of the photographed object was reconstructed in space near the plane of the lens array when the unit was illuminated with diffuse light from the emulsion side.

The three-dimensional color portraits that were made in this manner were examined by several observers. It was found that the portraits produce well a three-dimensional sensation; in addition they are high quality, have a large depth of field and correct color transfer. The impression is enhanced by the effect of the play of highlights on the eyes and by the reverse rotation of the images as they are examined in all directions: this imparts to the portraits a life that cannot be achieved by normal photography methods.

The resolution of the integral image, whose depth is equal to 200 mm, was 1 mm^{-1} at the front and rear planes, and was equal to about 3 mm^{-1} in the plane of best resolution. These values, when allowance is made for the viewing distance (1.5 m), correspond to an angular resolution of 1-2', which confirms the theoretical conclusions of Ref. 3 on the possibility of using the described method to obtain a good-quality three-dimensionsl integral portrait. At this same viewing distance the transverse dimension of the viewing zone is equal to 120 mm; this provides comfortable viewing conditions for the observer involving only small movements of the head.

Because of the multiplying properties of the array[5] a series of three-dimensional integral images and corresponding viewing zones existed in space. Therefore for large lateral movements of the observer's head narrow moire bands enter his field of view, separating the central zone of view from the adjacent one. However, this drawback is not fundamentally important and it can be practically eliminated by a special choice of the objective lens and array parameters. At the same time the presence of the additional viewing zones makes it possible for a group of observers to view the integral image simultaneously.

For the commercial manufacture of integral photographs on a film base a problem arises concerning their long-term storage. The fact of the matter is that possible shrinkage of the film can lead to a change of the microimage spacing on the film emulsion, thereby resulting in a change of the integral image parameters. To reduce shrinkage we can recommend rinsing the emulsion in glycerine immediately after development, cementing it to a glass substrate, and peripheral cementing between two glass plates. The 120 × 140-mm format integral photographs, obtained in such manner, have been demonstrated at the Leningrad Museum of the October Revolution for two years; no noticeable degradation of the image quality has been observed.

1. Yu. A. Dudnikov, Sov. Pat. No. 352,256, Byull. Izobret. Tov. Znakov No. 28, 144 (1972).
2. Yu. A. Dudnikov and B. K. Rozhkov, Opt. Mekh. Promst. No. 7, 6 (1979) [Sov. J. Opt. Technol. 46, 385 (1979)].
3. Yu. A. Dudnikov and B. K. Rozhkov, Opt. Mekh. Promst. No. 12, 38 (1979) [Sov. J. Opt. Technol. 46, 736 (1979)].
4. Yu. A. Dudnikov, Opt. Mekh. Promst. No. 5, 17 (1974) [Sov. J. Opt. Technol. 41, 260 (1979)].
5. N. A. Valyus, Stereoskopiya (Stereoscopy), Press of USSR Acad. Sci., Moscow, 1962.

On a metrological model of the reproduction of semantic luminance structures

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An approach is described to the metrological operations in the subjective perception of photographic images on the basis of the modern concept of correct tone reproduction and also to the exposure setting for picture taking.

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In everyday practice we are constantly placed in the position of observers evaluating luminance structures, i. e., combinations of certain localized luminances L_i within the limits of a given solid angle 2β. A special place among such structures is occupied by semantic structures, i. e., those structures in which the luminance gradations, elements, and fields carry additional socially significant informational, emotional, ideological and other obligations. Artistic photography, movies and television, for example, involve the reproduction of semantic luminance structures.

The reproduction process of nonsemantic structures is adequately well described by the MTF tool, whereas the subjective factor or the vision and psychological apparatus of man plays an important role for semantic structures. The latter can only be described statistically, and our knowledge of its functioning is still inadequate. However, the so-called reference concept of correct tone reproduction, formulated at the end of the 1960's, within the framework of the black-and-white photographic process,[1,2] the statistics of the densities, into which certain characteristic tones, objects and other elements in black-and-white photographic prints are transferred,[3] as well as a number of new pieces of information about the functioning of the vision mechanism[4] make it possible to develop a metrological model of the semantic structure reproduction cycle for the example of black-and-white photographic prints.

As is known, the two-step photographic process possesses a significant nonlinearity that is due in no small measure to the unique features of photographic paper[5]; up to now, however, there has been no emphasis on another, no less important cause of this nonlinearity, namely: the difference in the dynamic ranges of the objective and subjective phases of the reproduction cycle, which are practically independent[2,6] of one another. The statistics of the luminance intervals of photographic subjects have been analyzed sufficiently,[1] and the average interval for outdoor photography is taken equal to 2.2 log units. However, the prints are usually examined in rooms having some average overall illumination level, for which the corresponding average luminance interval is always necessarily less than 2 log units. Even if the density range of photographic papers were equal to the luminance interval of the average subject outside, we could not transfer adequately the latter onto the print without a selective lighting of it relative to the average illumination level in a given room. Thus, we have two dynamic ranges (in log units): G_1 of the objective phase, equal to the luminance interval of the photography subject; G_2 of the subjective phase, equal to the luminance interval in the room for a given illumination level of E_2 in it.

In the general case $G_1 >> G_2$. However, the relative in-