RGB image processing method for color classifying diamonds

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Abstract

Developing methods of automatic diamond sorting by color is one of the actual problems for diamond industry. Such sorting allows significant increase in productivity with simultaneous objective classification of crystals. The article considers method for classifying diamond according to their color based on diamond digital images registration and their after-treatment. Image processing allows us greatly to minimize the influence of the position, glare and individual particularities of the diamond on result of the measurement. The method provides sorting at the speed of 5 diamonds per second with false identification no more than 3-5%.

Keywords: Colorimetry, color saturation, color measurement, RGB coordinates, diamond sorting

1. Introduction

In diamond industry rough stones are classifying by size, form and quality. Diamonds with high clarity, ones with a slight tone of a color or of unusual color are considered the most expensive and are used to make jewelries. Crystals of saturated brown colors are regarded as less valuable and are processed to make grindstones, polishing powders, etc. One of the most significant quality factors of a diamond is the color [1-3].

In Russia the color sorting is carried out mostly by hand. The hand sorting is characterized by low productivity and high value and its results highly depend on the sorter's qualifications, his/her working conditions and the features of the diamonds being sorted (size, form, color). Therefore developing methods and means for diamond automatic color processing which allow us to increase the productivity and to exclude the subjectivity of the manual sorting are urgent. The obtained experimental results as for development RGB technology for color classification are presented below.

2. Problem

Diamond sorting by color is used by almost all diamond plants. To carry out the sorting they all have specially trained personnel and the sample collections, where diamonds of different size, form and quality are represented. There are the standards determining color groups of diamonds in accordance with the tone and color saturation. The Gemological Institute of America (GIA) classifies low saturation yellow and brown diamonds as diamonds in the normal color range, and applies a grading scale from 'D' (colorless) to 'Z' (light yellow). Russian Federation applies grading scale (1…9) C to diamonds of yellow tint (and some other), and scale (1…6) Brn to brown diamond.

According to State Standard P 51519.2 – 99 (RF) the basis of the diamond color classification is visual estimation of the color. The Standard determines the conditions required to carry out the estimation. The color is determined in comparison with the samples placed against the background of a white sheet of paper in daylight.

Following the procedure guarantees stable results disregarding the time and place of the sorting. Thus one has a well-tailored way to classify diamonds by their color. And the quality of the automated sorting should at least match the quality of the manual processing. Automated color classification should also match the one given by the experts. This could be achieved by determination of color parameters, the experts rely upon when they do the sorting. There are three basic parameters: the color itself, its intensity and the clarity of a stone. Technically speaking the color can be described as a dominant wavelength λ_d (a length of the wave of a radiation (absorption) spectrum matching the most powerful radiation. Color intensity *N* is a color parameter characterized by the clarity of a hue. It is describes as a ratio of the radiation power of a dominant wavelength and total power. A diamond's clarity *I* when measured automatically could be estimated as brightness level or luminance of a signal transmitted through the diamond. $I = I_0\tau$, where I_0 is the intensity of the luminance signal and τ is a diamond's transmission coefficient. The clarity mainly characterizes defectiveness of a diamond, showing the diamond has opaque inclusions and cracks.

Automatic diamond sorting by color is possible either through direct measurements of the color characteristics or through comparison with the samples as it is done by the experts. Having browsed the publications and made preliminary tests the authors came to the conclusion that the values of the measurements strongly depend on the form and the position of a diamond. It is because a diamond has the significant refractive index (2.7) which strongly affects distribution of transmitting and refracted light due to the dispersion and total internal reflection. Thus, sorting diamonds automatically one, together with the color, should measure and register their other characteristics like presence of flares, defects; a position of a diamond when being sorted.

Unbiased determination of a diamond's color is possible if combinations of the parameters measured are ultimate for the each color and tone of a diamond as they unambiguously determined by the experts (or at least by the properly trained sorters).

3. RGB classifying method

Let one considers the method of colorimetry which is implemented by the following procedures: a diamond is being put in white light and the light having transmitted is being registered by three receivers with different and quite narrow spectrum ranges. Or a diamond is lightened by red *(R)*, green *(G)* and blue *(B)* beams one after another which, transmitting through the crystal are being registered by one photoreceiver. The values of signals registered are displayed as RGB coordinates. There are many methods to determine a color by RGB components. The transformation matrixes are linear. That means that transformation of the color coordinates has provided no additional information if color classification is carried out. So choosing a color coordinate system one should rely upon its ease at determining the boundaries identifying diamonds belong to particular color category.

One should also highlight the positives of the photoelectric method: it is easy in use and is well-adopted to visual perception of colors. But when color characteristics of a diamond change the method takes too much time and result in significant measurement error since it does not take into account the flares, inclusions and the form of the diamond.

The authors investigated into the colorimetry method based on image registration by the digital camera (Fig. 1) which forms detached RGB channels.

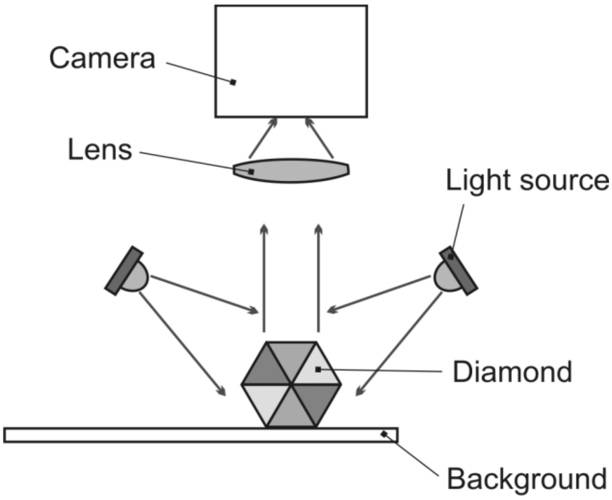

Fig. 1. Optical scheme of measurements with the use of digital color camera.

The sensitivity curves of the matrix elements in their characteristics are close to the curves of a human eye. That is why the camera can be regarded as a model of the eye that allows calculating RGB values, averaging and interpolating the data for each pixel of the image. Each pixel of the image contains information on the three RGB coordinates. Using the camera guarantees the results of automated sorting have matched the ones by the experts. Additional image processing allows excluding the flares, inclusions, defects of a diamond's shape and so on, increasing the reliability of the classification procedure.

4. Experimental results

For the preliminary test of the digital registration and image processing capabilities the authors took about 100 photos of diamonds using a digital camera. To take such a photo one positioned a diamond on a white horizontal table. The refracted and scattered light had been registered by the camera's matrix. Figure 2 displays some of the images taken.

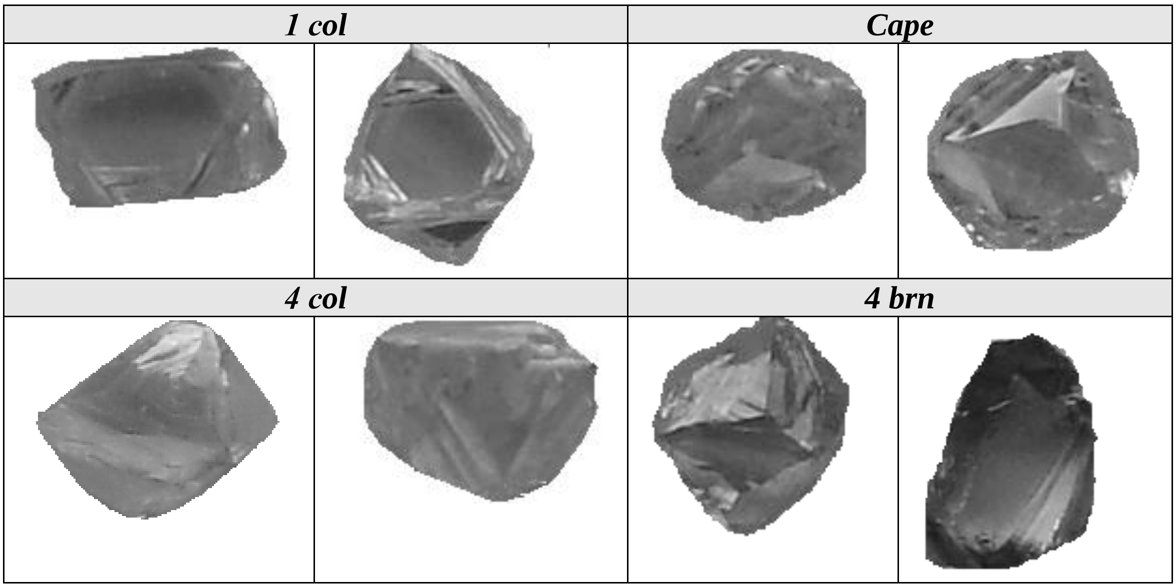

Fig. 2. Images of diamonds of different color categories taken by the camera:
1col, 2col, 4col - light yellow; Cape – yellow; 4 brn – brown diamonds.

The images displayed demonstrate difference of the shapes, presence of the flares and structural irregularities, which, in their turn, significantly affect the results of colorimetry. Despite the fact that the camera's spectral sensitivity had not been attested and the images saved in JPEG format had lost some thin differences in the consecutive areas of an image the results achieved in majority of ways coincided the results of the photometric and spectrometric measurements by other authors. The coincidences were observed as in the relative results and their scatter as in the absolute estimations [4].

The images were processed with MathCAD package. First one cut out the background. Then from the point array of each image one excluded the brightest points (the flares), the darkest ones (the defects), as well as ones with minimum color saturation. The processing of the digital images resulted in significant increase of the result processing adequacy. The comparative analyses carried out after the image processing showed 90 per cent of the diamonds had been sorted correctly. The high percentage proves the results of such automated sorting are close to the one carried out manually.

More over, a full-scale investigation into the colorimetry method has been carried out at the test model, designed at Technological Design Institute of Scientific Instrument Engineering of Siberian Branch of the Russian Academy of Sciences. The model of the sorting apparatus used a digital video camera instead of a digital photo camera.

About 750 stones have been put through the model. The boundaries for the color classification were determined through measuring color characteristics of diamonds from sample collections. Then the data obtained were processed by the authors themselves to determine the boundaries for diamond color saturation and boundary wavelength to sort yellow stones from brown ones.

The sample collections range diamonds as: Stones (well-formed crystals with insignificant divergences; dog-tooth ones with faces improperly developed), Cleavage (poorly formed, crystal faces not developed; chips, crystals with growth); Flats (slender chips with crystal faces not developed); Maccles (spinel twins and their chips with properly developed faces).

The experiments carried out revealed that the saturation of the stones depends on their isometric value. The values calculated for Flats and Maccles are lower than for diamonds of similar in color but more isometric in shapes (Stones). From crystals of the same size and color, the slender ones seemed least saturated, while the crystals poorly formed exhibited the highest value of saturation.

Processing the information on the shape of the stones guarantees satisfactory accuracy when sorting diamonds by color. But even in the case when color sorting is carried out without preliminary sorting by shape the simplified digital image processing allows minimizing the effects of flares and defects affecting the accuracy of the color sorting.

Figure 3 displays the results of measurements for color saturation N and dominant wavelength λ_d, obtained at the test model described. The figure indicates the classification for the groups of the diamonds. The diamonds of different groups has rarely been mixed. The percentage of diamonds of other colors in one color category has not exceeded 1-3%.

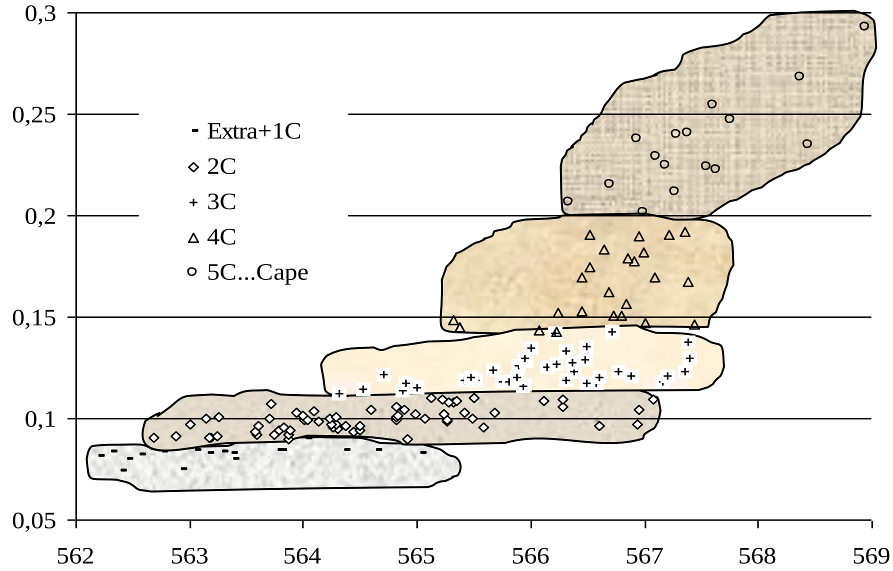

Fig. 3. The results of measurements for the color saturation and the dominant wavelength based on processing of diamonds.

5. Conclusion

Thus we have studied the perspectives of the method for diamond sorting, based on registration of a diamond and further processing of the image obtained. The method allows minimizing the effects affecting the accuracy of the sorting, so its results match ones when diamonds are sorted manually by a qualified expert. The results of the experiments have demonstrated the increasing of the sorting accuracy up to 95 per sent when proper exclusion of flares, black inclusions and the areas adjoining crystal edges was made. We have developed a model of an optic-electronic system for diamond sorting by color, which allows sorting in 10 color categories and sorting rate of 5 diamonds per second.

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