A Color Indexing System Based On Perception (CISBOP)

Dirk Neumann & Karl R. Gegenfurtner

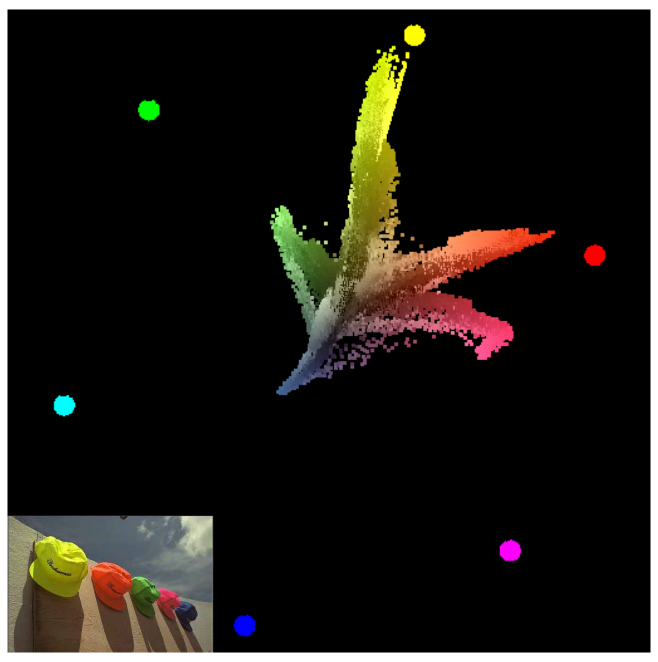
Max-Planck-Institut für biologische Kybernetik
Spemannstraße 38 • 72076 Tübingen • Germany

1. Introduction

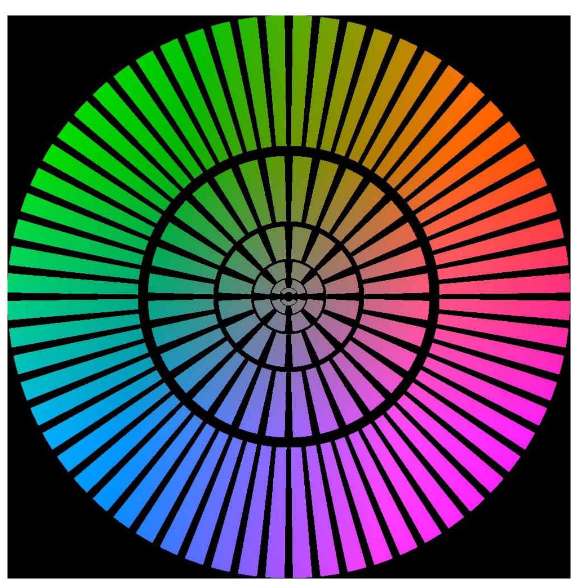
Color is an important feature for searching large databases of images, since it is invariant with respect to camera position, object orientation and size, and partial occlusion. There are currently many color-based image indexing systems (e.g. Flickner et al., 1995), which all basically work by building color histograms in RGB space. Our goal was to construct a color-indexing system based on the known properties of the human color vision system, and to establish a performance measure to evaluate the system.

2. Color Space

For each image, we built a color histogram by converting the RGB triplets for each pixel into color-opponent coordinates. These luminance, red-green, and yellow-blue coordinates correspond to the cardinal color directions underlying human color vision (Krauskopf, Williams & Heeley, 1982).



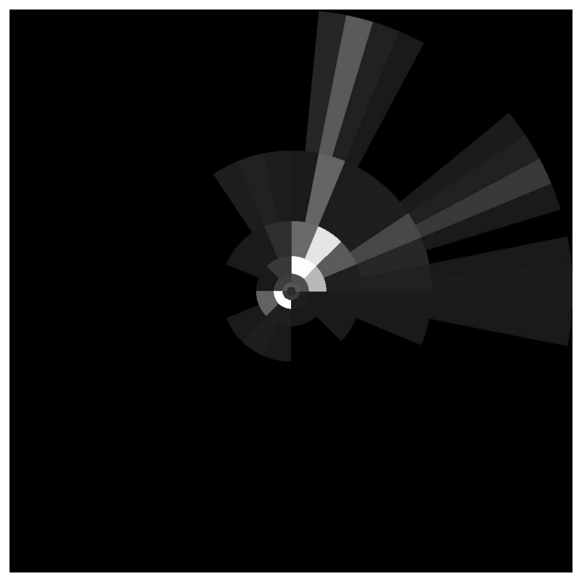
The outcome of the transformation process can be visualized by plotting the pixel colors according to their chromaticity coordinates in the color plane spanned by the color directions red-green and yellow-blue (or hue and saturation in polar coordinates). The illustration shows the chromaticity distribution for the image with the hats at the bottom left. If more than one pixel had the same chromaticity, the luminance of these pixels was averaged.



For indexing, the color circle was split into 127 segments. The categories were constructed so that the number of hue categories increased with increasing saturation. Six different rings were used for saturation, with the radius doubling as saturation increases. Thus, there is little discrimination of hues for unsaturated colors, whereas there are 64 different hues at the most saturated level.

3. Color Index

Two different histograms were built, one using the frequencies with which the different colors occurred, and another one that used the average luminance level of each color segment.
The color distribution obtained in the transformation process was mapped into these 127 segments. Colors falling below 5% or exceeding 95% of the maximal possible luminance were categorized as either black or white.



For the frequency histogram it was counted how many pixels belong to each luminance-independent category. The vector was normalized by the total number of pixels in the image. Thus, the segment value gives the proportion of pixels within a color segment. The chart above shows the frequencies with which the color categories occur in the sample image with the hats (white is highest).

For the luminance histogram the luminance was averaged for all pixel within each segment. The number of pixels belonging to a segment does not contribute to the luminance histogram. The chart shows the mean luminances in each segment for the sample image.

4. Search System

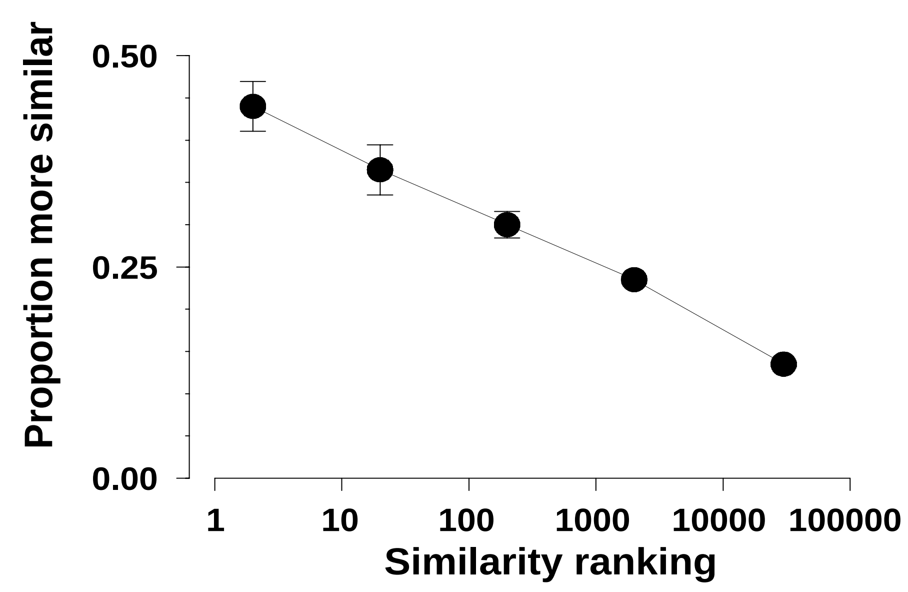
The image database was a large commercially available (COREL) image collection consisting of 60.000 digitized photographs.
We used the query-by-example strategy for searching. The query image could be choosen out of a set of random images, the latest query results, or selected manually. Based on the feature vectors, a distance between the query image and each image in the database is calculated. The nearest images are presented to the user.
A minimum metric was used to calculate similarity. The minimum of two vectors x and y was defined as the sum of the minima m_i of the corresponding components x_i and y_i. Thus, the sum of the components m_i is the proportion of pixels of the two images belonging to the same categories.

6. Experiment

To evaluate the performance of the color indexing system we ask 5 human observers to make similarity judgements.
Three images were presented: a randomly selected query image at the top and two test images below. One test images was always the best match while the other image had either rank 2, 20, 200 or 2000 in the result list, or was a randomly selected image.
The number of negative responses - the variable test image was judged more similar to the query image than the best match - was counted for each position. The percentage of these judgements gives an estimate of the average perceived similarity.

7. Results

For 14% of the queries a random image was judged more similar than the best image.
The logarithm of the rank obtained by color indexing correlates highly with the judgements of human observers ($\rho = 0.99$):



8. Conclusion

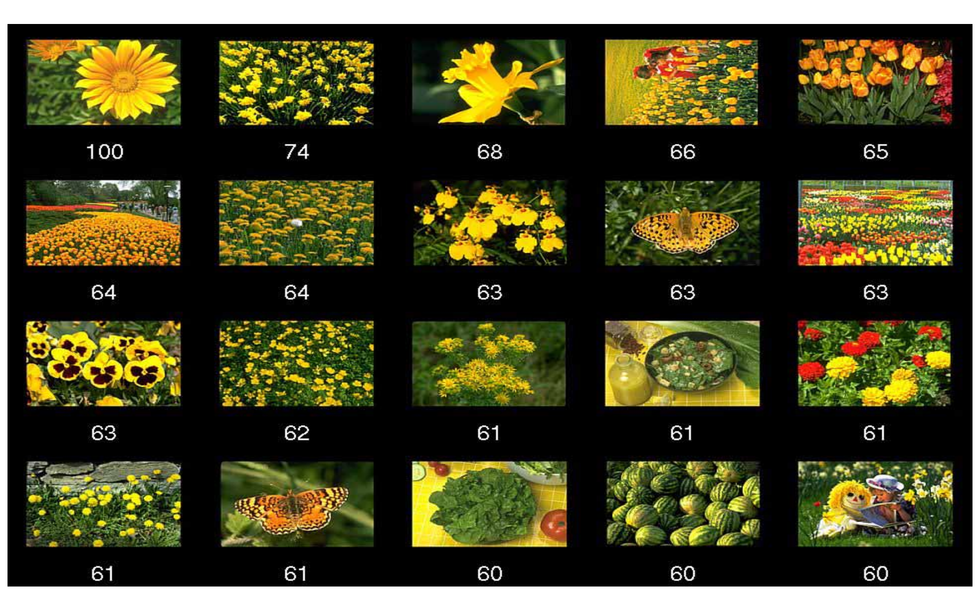
The results suggest that the color indexing technique used creates a distance measure that can be related to human judgments of similarity.
The order induced by the color index could not only be used to select a few similar images but contains information about similarity even for relatively distinct images. This may be exploited for stepwise refinements of queries.
We are currently investigating including spatial information into the indexing system.

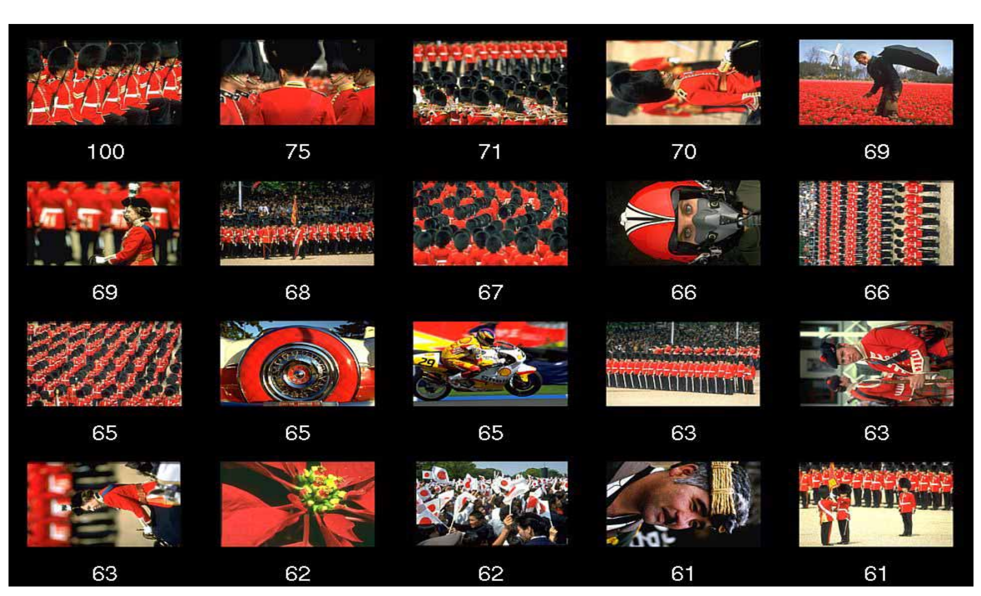
9. References

Krauskopf, J., Williams. D. R. and Heeley, D. W. (1982) Cardinal directions of color space. Vision Research, 22, 1123-1131.

Flickner, M. et al. (1995) Query by image and video content - the QBIC system. Computer, 28, 23-32.

5. Query Results





The images at the top left were used as query images. The minimum of the frequency vectors (the proportion of pixels belonging to the same color segment) was used as the distance measure.
The numbers below the images show the percentage of pixel colors shared with the query image.