Beverage cap mosaic

Jonathan Andersson - jonan270

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Contents

1 Abstract

This project aims to reproduce images using a set of smaller images of bottle caps. This is achieved by calculating average *CIELAB* colors for a circular area using polar coordinates, and then placing bottle caps of similar color at the corresponding position. The project presents two different methods of reducing the image set. The mean *SCIELAB* measurement of quality is used as an objective measurement of reproduction quality.

Overall, reproduction quality is generally good with reproduction images resembling the original when viewed from a distance, while also retaining the detail when inspected closely.

2 Introduction

This project aims to replicate images using a set of beverage caps leading to a mosaic-like effect. The reproduced image is then to be compared to the original using an objective quality measurement in order to examine how well the image is replicated.

In total, 100 images of caps were used in the project. The size and content of the image set is based on what was available through the source images used: Eric Conrad's set [1], Erich Ferdinand's set[2], A Yee's set[7] as well as a total of 11 caps which were photographed personally. While the image set could be extended further, the image set will later be reduced to just 50 regardless.

For the sake of efficiency, the resolution of the cap images had to be reduced significantly. By default, a resolution of 40x40 for each cap image is used since this still allows some of the finer details of the cap to be visible when zooming. The program can also be toggled to work more efficiently for smaller images by using images with a resolution of 20x20. The final minimum image resolution is based on the width of 50 caps.

The reproduced image looks similar when viewed from a distance, regardless of which resolution is used but detail is lost when looking closely at the image using lower resolution.

(a) Close-up for using high detailed images of resolution 40x40

(b) Close-up for using low detailed images of resolution 20x20

Figure 2.1: Close-up images of caps using different resolution for cap images.

3 Method

This chapter describes the method used to achieve the desired result. If the image to reproduce is smaller than 50 times the width of the cap images used, a warning message is displayed and the image is resized to the point where the width is equal to 50 times the width of the cap images used. If the image is larger, the image reproduction is set to be of equal size as the original.

3.1 Handling circular images

Since caps are circular, a large portion of each cap image consists of a black background colour, see Figure 3.1. In order to optimize for circular images, polar coordinates were used to extract and write pixel values in a circular area, see eq(3.1).

$$\begin{aligned} x &= r \cdot cos(\theta) \\ y &= r \cdot sin(\theta) \end{aligned} \tag{3.1}$$

By iterating with an angle $\theta \in [0, 2\pi]$ and a radius $r \in [1, r_{max}]$, where r_{max} is based on the image width of the caps used, pixel values at positions (x, y) can be read and written.

Caps are placed by offsetting the position for each even row by the radius of a cap. By doing this the effective area, taken into consideration when searching and calculating average lab values, is increased compared to if the whole image would be iterated pixel-wise.

3.2 Image pre-processing

The first step of the algorithm consists of pre-processing all images of caps. Each cap image is stored in a cell array. By using polar coordinates as described earlier, an average color in CIELAB color space for a cap can be calculated and also stored in separate cell array using the same index value as the array containing images. This reduces computation time limiting the amount of times images have to be read from disk.

Figure 3.1: Image of a cap with resolution 40x40, used in the project.

3.3 Image set reduction

Some average lab values obtained from the original image set were very close in terms of euclidean distance see Figure 3.2(a). This means that some images could be removed without having a large impact on reproduction quality. In doing so, the program runs faster due to not having to iterate over as many average colour values as otherwise.

In the method implemented, the user can choose between two different methods for reducing the image data set. The amount of images used were set to a maximum of 50.

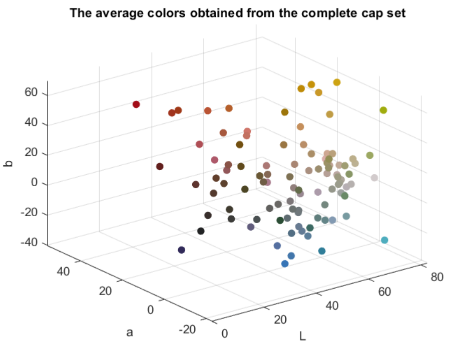
3.3.1 K-means clustering

One method implemented to reduce the image data set was to use the Matlab function *kmeans*. The k-means clustering algorithm is a data partitioning algorithm that assigns observation values to a pre-specified amount of clusters[6].

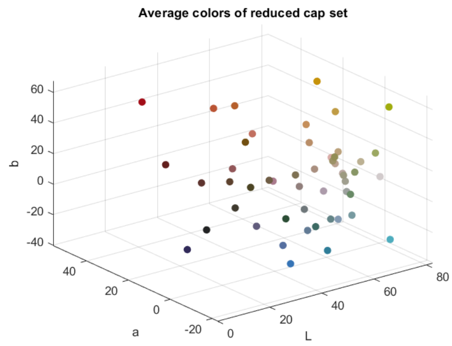
By setting the amount of clusters equal to the amount of desired images to be used, a representative for each cluster can be chosen, see Figure 3.2(b).

3.3.2 Image indexing

The second used image reduction method utilizes the Matlab function *rgb2ind*. This function makes use of minimum variance quantization to limit the amount of colors in the image to a specified amount[5]. By using this function to find a set of colors equal in size to the amount of cap images to use, and then iterating over the cap images to find the caps which most closely relate to that colorset, the set of caps used is optimized to the specific image to be replicated.



(a) The colors obtained from the full image set.



(b) The colors obtained after reducing the amount of images used to 50 using the clustering method

Figure 3.2: The average lab values of the cap set before and after reduction using clustering.

3.4 Picking the optimal cap

Caps are chosen by getting the average CIELAB colour for a circular area with equal radius size as the caps used. The cap having an average lab colour with the smallest euclidean distance from the colour to be replicated is then chosen.

3.5 Measuring of reproduction quality

In order to compare and measure the image quality for the method used, an objective measurement of quality is necessary. The chosen method, *SCIELAB* works well for static images[3].

The desired effect of the project is to generate a reproduction that resembles the original image when looking at from a distance, while revealing the detail of the bottle caps when looking closely. When using the SCIELAB there is a connection between viewing distance and the sample per degree value. By specifying a large value for sample per degree, the effect of observing the image from a large distance can be achieved, see eq(3.2) [4].

$$SamplePerDegree = ppi \cdot d \cdot tan(\pi/180) \tag{3.2}$$

By using a distance d of 3 meters or 118 inches, and a $ppi = 109$(pixels per inch) value based on the screen used a value $SamplePerDegree = 224.5070$ was obtained.

4 Result

This chapter presents the result obtained using the method described in 3.

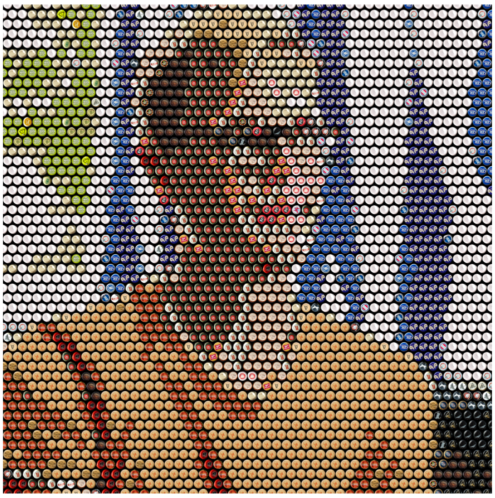
4.1 Results from using clustering to reduce image set

The following section presents the results from implementing the clustering method described in 3.3.1.

4.1.1 Portrait image

The result obtained from reproducing a portrait image using the clustering method, see Figure 4.1 looks visually similar to the original from a distance but details in the facial area is a bit lacking. The image reproduction took a total of 171 seconds and gave a mean SCIELAB result of 1.9889.

(a) Original portrait image, with a resolution of 1080x1080.



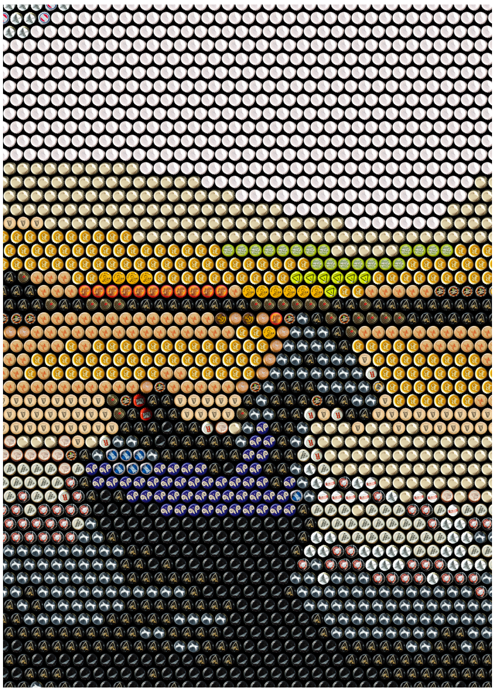
(b) Reproduction result obtained when using the clustering method to reduce the amount of caps to 50. Cap images are of resolution 40x40.

Figure 4.1: Image reproduction of a portrait image using the clustering method to reduce the image set.

4.1.2 Dark image

The sky in the reproduced image obtained from reproducing a dark image using the clustering method, see Figure 4.2, is quite different from the original image. The smooth gradual shift in color is difficult to replicate and results in the sky looking blocky. The rope connected to the pool toy is hard to see in the reproduction. The image reproduction took a total of 111 seconds and gave a mean SCIELAB result of 2.2950.

(a) Original dark image, with a resolution of 1080x1509.



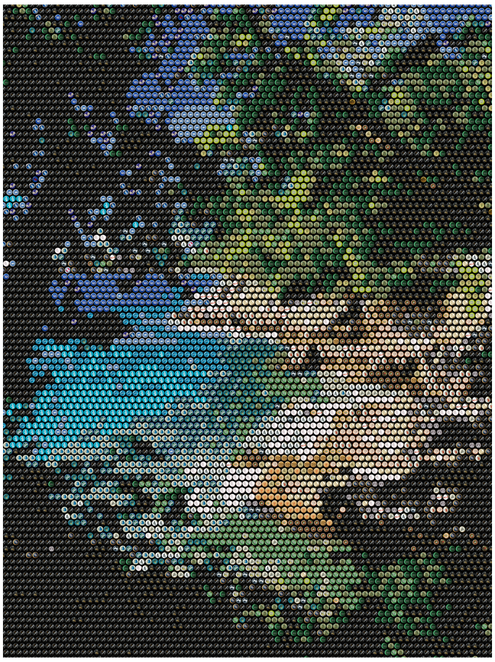
(b) Reproduction result obtained when using the clustering method to reduce the amount of caps to 50. Cap images are of resolution 40x40.

Figure 4.2: Image reproduction of a portrait image using the clustering method to reduce the image set.

4.1.3 Landscape image

The result obtained from reproducing a landscape image using the clustering method, see Figure 4.3 is visually similar to the original. However, some detail is lost. The small object located on the rock shore is lost in the reproduction. The image reproduction took a total of 1053 seconds and gave a mean SCIELAB result of 1.2272.

(a) Original landscape image, with a resolution of 3024x4032.



(b) Reproduction result obtained when using the clustering method to reduce the amount of caps to 50. Cap images are of resolution 40x40.

Figure 4.3: Image reproduction of a landscape using the clustering method to reduce the image set.

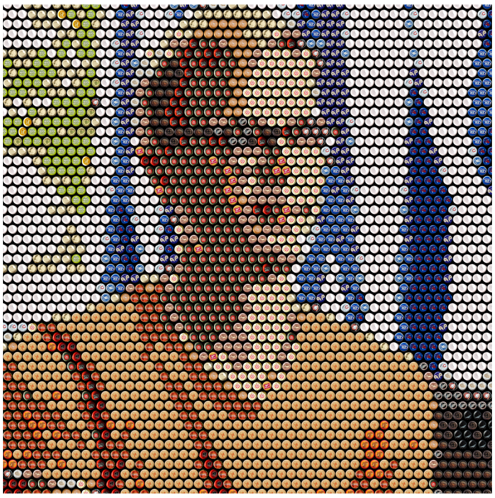
4.2 Results from using indexing to reduce image set

The following section presents the results from implementing the indexing method described in 3.3.2.

4.2.1 Portrait image

The result from using the indexing method as described in 3.3.2 to reproduce the portrait image is slightly improved visually with clearer facial details, see Figure 4.4. The image reproduction took a total of 170 seconds and gave a mean SCIELAB result of 1.9160.

(a) Original portrait image, with a resolution of 1080x1080.



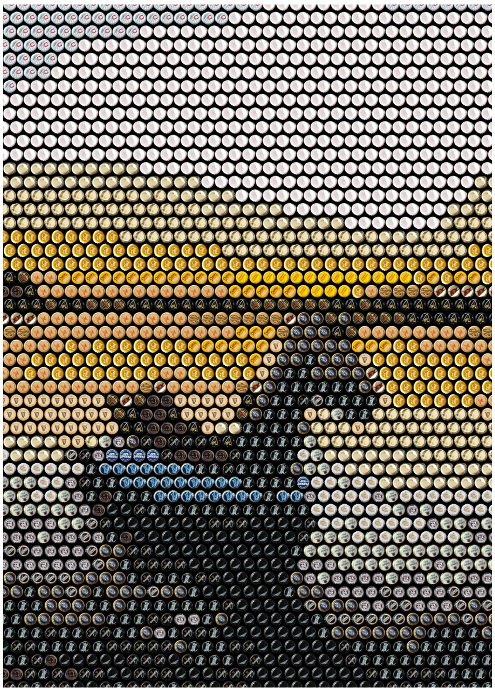
(b) Reproduction result obtained when using the indexing method to reduce the amount of caps to 50. Cap images are of resolution 40x40.

Figure 4.4: Image reproduction of a portrait image using the indexing method to reduce the image set.

4.2.2 Dark image

Using the indexing method 3.3.2, image looks slightly better with a more even transition of colors in the sky, see Figure 4.5, compared to the resulting image when using the clustering method. The image reproduction took a total of 116 seconds and gave a mean SCIELAB result of 2.2353.

(a) Original dark image, with a resolution of 1080x1509.



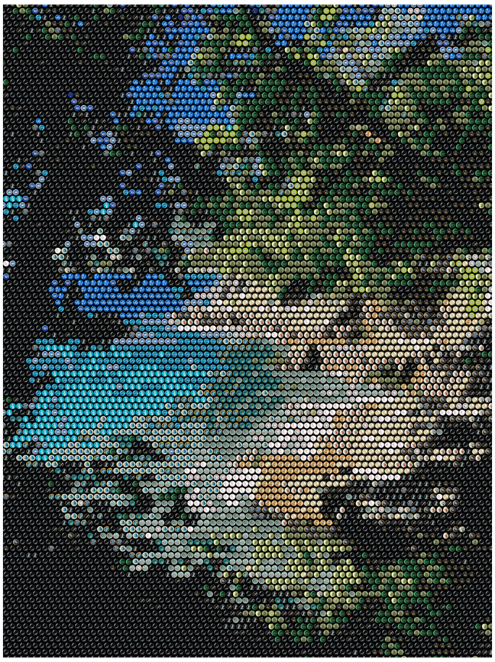
(b) Reproduction result obtained when using the indexing method to reduce the amount of caps to 50. Cap images are of resolution 40x40.

Figure 4.5: Image reproduction of a dark image using the indexing method to reduce the image set.

4.2.3 Landscape image

The landscape reproduction is visually very similar between the indexing and clustering method, see Figure 4.6. The image reproduction took a total of 1039 seconds and gave a mean SCIELAB result of 1.1739.

(a) Original landscape image, with a resolution of 3024x4032.



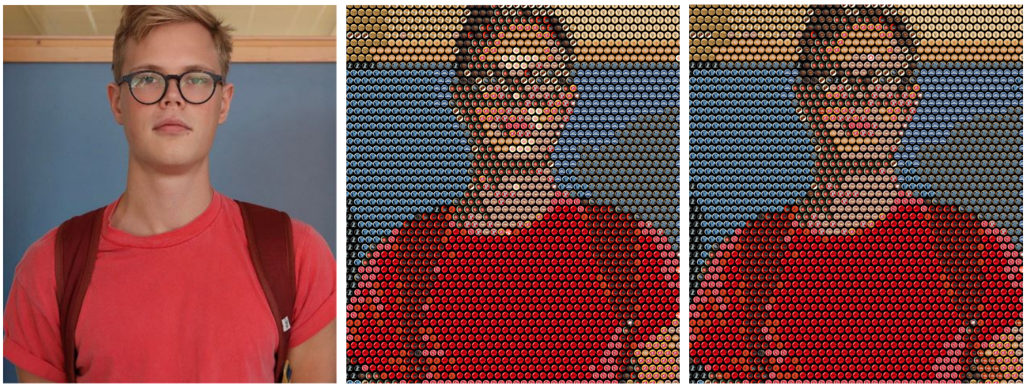
(b) Reproduction result obtained when using the clustering method to reduce the amount of caps to 50. Cap images are of resolution 40x40.

Figure 4.6: Image reproduction of a landscape using the indexing method to reduce the image set.

4.3 Resolution comparison

As mentioned in 2, different cap image resolutions can used for image reproduction which can be used to improve performance for smaller images. For a small portrait image, see Figure 4.7.

The image reproduction took a total of 154 seconds and gave a mean SCIELAB result of 1.3344 when using images of size 40x40, see 4.7(b). The image reproduction took a total of 65 seconds and gave a mean SCIELAB result of 1.0282 when using images of size 40x40, see 4.7(b).



(a) Original small image, with a resolution of 420x477.

(b) Reproduction result obtained when using the indexing method to reduce the amount of caps to 50. Cap images are of resolution 40x40.

(c) Reproduction result obtained when using the indexing method to reduce the amount of caps to 50. Cap images are of resolution 20x20.

Figure 4.7: Image reproduction of a small portrait image using the indexing method to reduce the image set. The cap image resolution varies.

5 Discussion

Overall, the the desired effect is achieved. By looking closely at the reproduced images the fine details of the caps can be seen while the reproduced images also closely resemble the originals from a distance. As seen in 4, the resulting reproduction seem to be slightly better when using the indexing method to reduce the image set. This is reflected both in the SCIELAB mean values and, in my opinion, visual quality.

The possibility to reduce image resolution improves efficiency for small images without impacting reproduction quality when viewed from a distance. There is however the issue that image resizing only occurs for small images. This means that for large images, reproduction can actually take longer time since more bottle caps need to be placed in order to reach the same resolution as the original image.

A possible issue is that some caps are far from circular leading to extra black pixels being included in the color calculations. This means that the program likely has some level of bias toward darker colours.

A slight downside to having non-square grid positioning of caps is that it is impossible to replicate completely straight lines. This gives straight edges a slight fuzzy appearance which could have been avoided if a square grid was used instead.

A possible improvement would be to combine the SCIELAB measurement of quality with some other type of objective quality measurement, such as *PSNR*. This could possibly lead to better measurements of quality that better represent the percieved quality difference. It has however been shown that SCIELAB generally better correlates to subjective quality perception for static images than PSNR[3]. Optimally, a number of quality measurement methods such as *SSIM*, *SNR* and PSNR could be presented together to see outlier cases and identify which methods seem to perform the best for this specific case

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