Lecture 13 - 4: Another Clustering Example: Image Quantization

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So Google News example is an example of use of clustering for visualization. Let's look at a very different application of clustering and this time for data compression. So the specific application that I will talk about is called:

IMAGE QUANTIZATION

So let's assume that a typical picture would have 1,024 by 1024 pixels. Now, each pixel is encoded by 24 bits because you have 8 bits for red, 8 bits for blue, and 8 beads for green. So therefore a typical image would be the number of pixel multiplied by the number of bits we need to store each pixel:

- red - 8 bits
- green - 8 bits
- blue - 8 bits

$$1024 \times 1024 \times 24 = 3\text{Mb} \tag{1}$$

Let's say I want to compress it and to use much less space to get high-quality image.

So one option for me is to say that instead of using such a rich representation of the pixel I am going to greatly limit myself: I will just allow myself, let's say, to have 32 colors.

First of all, 32 colors is not that bad, but let's say we are just limited to use only 32 colors. In this case, we would need only two 2^5 (5 bits) to encode them, which makes it much easier.

So now if we are looking at the same pictures that we had before, we will have 1,024 by 1,024 pixels, and then each one of them would be just represented by 5 bits.

In addition, we also would need to store the dictionary which remember how we can translate each one of these colors to our original encoding in this 24-bit representation.

So again, this part will be just representing every pixel by 1 of 32 colors, and this part would remember how to translate our colors that we selected in the encoding of the 24 bits, which was original encoding of our pixel. In this case, we would have much smaller representation of the image.

$$1024 \times 1024 \times 5 + 32 \times 24 = 640\text{Kb} \tag{2}$$

So the question that you may be asking yourself, now I started with looking at this very high-resolution image where we can encode so many different colors, and I limited myself just to a few colors: How well does it work?

So let's take a look at a concrete picture and see how this process actually reflects on the picture quality.

Figure 1: 24 bits color image

So here you can see an image from a cartoon, and it uses quite a number of colors. And if you remember how the pixel is represented, in theory we can have 2^{24} different colors.

So now I will go to an extreme. And instead of using so many different colors, I would allow you to use just two colors.

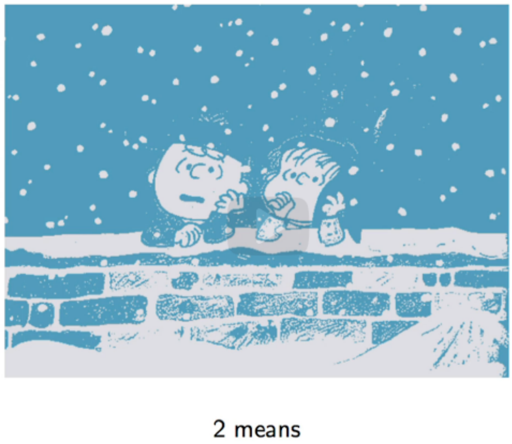


Figure 2: 2 colors

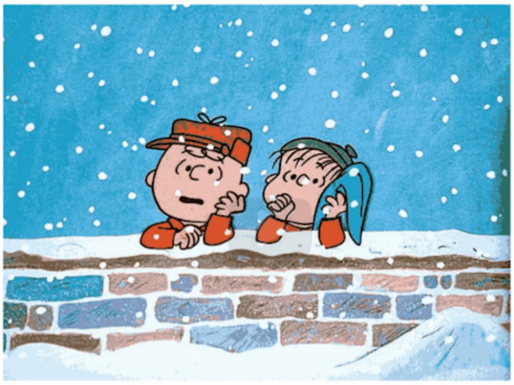
And in this case, we can see this image represented with two colors. Obviously we lose most of the details but we can still recognize the characters. We will get great compression rate but will clearly negatively impact the quality of the picture.

Now, I would give you a bit more colors and allow you to use four.

Figure 3: 4 colors

In this case, it already looks a lot like a real cartoon, but we can still see that there is a big difference in resolution between the original image and this particular one.

However, as we continue to increase the number of colors, for instance here we have 16 colors,



16 means

Figure 4: 16 colors

we can clearly see that this image looks so much better, and it looks very close to the original image.

Now if I would use 32 colors, as the example that I showed you on the board previously, here I would say that for untrained observer, it will be almost impossible to distinguish this image from the original image.

32 means

Figure 5: 32 colors

So here we can say that we really hit a sweet spot between compressing the image but at the same time preserving the quality of the color of the image.

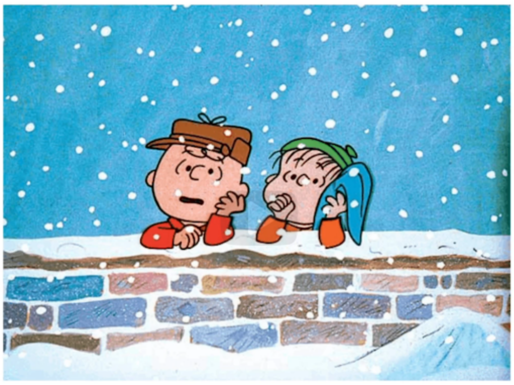
I will continue, I would show you 64 colors:

64 means

Figure 6: 64 colors

Again, it's even more precise.

And finally in 128 colors, we clearly will be unable by human eye to distinguish this picture from the original painting.



128 means

Figure 7: 128 colors

But what this progression between the number of clusters, the compression rate, and the quality brings us a very important point about the number of clusters and the impact on the resulting quality because here we have two contrasting goals:

- One goal is to make our image as compressed as possible.
- The second goal is obviously to preserve the quality.

And you have control over it by deciding how many clusters do you have, and it will depend on your space requirement, on your output requirement, and so on. As a developer, you can decide what is your perfect number of clusters K should be.

So now I concluded the description of this example, and I want to bring to your attention these two examples of clustering that we've seen:

- Google News visualization.
- Image quantification.

In both of these examples, we went through the same process.

1. We started by taking our instances and representing them as vectors:
    - In the case of Google News, it was stories that we translated using bag of words into a vector.
    - In teh case of the image, it was a pixel which we had represented as a vector of 24 bits.
2. The second step for us was to find a similarity measure which can compare between these two vectors.
3. And finally, we would use some clustering algorithm which would tell us how to group them.

So in this case, for instance, after we finished the grouping, we will select one representative color for the cluster and use them in the picture.

In the case of Google News, we selected one representative story to show as a central story in the news.