27 Increasing the Error Tolerance in Transmission of Vector Quantized Images by Self-Organizing Maps

Jari Kangas

In this study we consider an image compression system for its transmission error-tolerance properties. Efficient data compression is needed in image transmission applications. That is, because images consist of such a large number of elements. On the other hand, the image data can be compressed with high compression ratio, because the nearby pixels in images contain rather similar values.

The compression method used in this study is vector quantization (VQ), which is a powerful approach, but usually rather sensitive to transmission errors. It has been shown that the VQ codebooks produced by the Self-Organizing Map algorithm are comparable in quantization accuracy to codebooks designed by the LBG algorithm. Vector quantization is a very powerful compression method which naturally takes into account the redundancy of nearby image elements. The method considers vectors that are collected of nearby pixels in an image, a usual choice is to take a square of 4 by 4 (or 8 by 8) pixels. The compression happens when the vector is represented by an index to one model vector selected from a suitably designed codebook. The selection is done in such a way that the error occurring while replacing the original vector by the model vector is minimum.

The main problem in vector quantization is to design such codebooks that the average representation error over the compressed image is minimum. The above description is valid when there happens no errors in the index transmission. Then the codebook indexing can be done independent of the model vectors. If there are errors in the index transmission, we must consider the index relationships and the model properties together. The main problem is that if the codebook is indexed in an unordered manner, and if the transmitted index is changed to some other index, the representative model vector might change to a completely different model vector. The situation would be very different if we could order the codebook indexes in such a way that those codebook indexes which are easily mixed (due to transmission errors) would represent rather similar model vectors.

The Self-Organizing Map is trained in such a way that the model vectors in the map are spatially ordered after training, i.e., the neighboring model vectors in any place and in any direction of the Map are more similar than the more remote ones. This gives the idea of using the array coordinates of the Map as indexes in vector quantization. If we define the neighborhood function in the Self-Organizing Map training in such a way that the easily mixed models are always neighbors in the Map array, the training algorithm will ensure that the desired properties are achieved.

In other studies error-theoretic considerations were applied to the design of a VQ codebook for noisy environment. The algorithm turned out to be almost identical to the Self-Organizing Map algorithm. The identity was achieved when it was required that the training neighborhood was defined by the likelihood of changing an index to another one.

To demonstrate the performance of the SOM based error-tolerant image compression system, two transmission coding systems were designed. In the first scheme we used a digital pulse amplitude modulation (PAM) model with eight possible modulation amplitudes. The errors in the PAM model are amplitude level changes due to channel noise. As a second coding scheme we used a binary symmetric channel (BSC), where the errors were independent bit changes.

The SOM dimensions for codebooks had to be selected according to the principle of transmission. For the PAM transmission line, we selected a three- dimensional SOM, where there were 8 units in each dimension. The total number of codebook models is then 512. Each image block was transmitted over the PAM transmission line in three codes, one for each coordinate. Because the errors in each coordinate was independent of the others the probability of error in an index was considerably higher that the probability in a single code.

For the BSC channel we used a 9-dimensional SOM, where there were only two units in each dimension. The total number of units was then the same 512 as in the PAM model.

In the figures below two reconstructed images transmitted over a simulated PAM line are shown. In these the probability of errors was 0.1, which means that more than 40 % of the indexes were erroneous in the receiving end of the transmission line. In the image with random order the errors are usually rather severe. For example, in the middle of dark areas there are light blocks, and dark blocks are inserted in light areas. In the image with error-tolerant coding the errors are of different nature. For instance, in the dark area the erroneous blocks are never light, but "almost" dark. The subjectively experienced qualities of the images differ significantly, although the same number of errors were present in both.

Figure 44: The encoded and decoded images after transmission through a moderately noisy ($p = 0.01$) channel. The image on the left has been vector quantized with a nonordered codebook, and the image on the right with an ordered codebook, respectively. The subjectively experienced qualities of the images differ significantly, although the same *number* of codeword errors was present in both images.