**Title:** REDUCTION OF BLOCKING ARTEFACTS IN IMAGE DECOMPRESSION SYSTEMS

**Abstract:** A method and apparatus for reducing blocking artefacts in a decompressed image signal includes inputting the decompressed video signal and detecting locations of block and image content edges therein. Image content and block edges are discriminated between to remove or conceal the image content edges and the remaining block edges transformed to produce an error correcting signal to smooth the block edges at the detected locations in a delayed version of the decompressed video signal.
Reduction of blocking artefacts in image decompression systems

This invention relates to reduction of blocking artefacts in image decompression systems.

Image compression systems are now well established in delivery and storage of audiovisual media. These systems reduce bandwidth or storage requirements of video by using spatial and temporal redundancy in an image as well as mathematical transforms such as Fourier, discrete cosine and entropy coding that minimise a number of symbols needed to represent the image in a compressed domain.

A common technique used in such algorithms is reduction of spatial information by using block-based mathematics on groups of adjacent picture elements (pels). This commonly involves a discrete cosine transform or integer transforms that represent the spatial information in the frequency domain. This allows two means of compression of the image: first a differentiation can be drawn between significant and less significant frequency components with the latter being discarded, second the remaining components can be quantised by dividing by a variable called a quantiser scale code.

An advantage of quantising the frequency components arises in an entropy coding stage which usually follows quantisation. More strongly quantised coefficients will pack into fewer symbols on application of a well-designed entropy-coding algorithm.

However, this quantisation leads to an artefact called blocking. Rounding errors from the division of the coefficients by the quantiser scale code tend to result in a spatial distortion of the coded image within a block of pels operated on, but more significantly from one block to an adjacent block there will frequently be an abrupt discontinuity of luminance or chrominance levels at the block boundary following decompression.

Figure 1 shows schematically a graphical view of the results of block-based quantisation, showing a representation of the luminance level of a two-dimensional parabolic curve. Groups of adjacent pels in an 8 by 8 block have been modified to represent an approximation of the artefacts introduced by block based coding.
This is a significant impairment to the image and, being a non-linear and artificial error, tends to impact strongly on a viewer's perception of the image quality on decompression.


These known approaches involve softening an image at fixed block boundaries leading to a further loss of resolution. The known techniques also rely on a fixed grid of blocks and do not allow for the appearance of block edges through spatial prediction off this fixed grid.

Many of the proposed systems also require knowledge of the quantiser scale code used to divide the coefficients in the encoding stage. This requires that this information is passed on by some decoding apparatus to the de-blocking system or that an estimate is made of the quantiser scale code.

However, it may not be possible to obtain the quantiser scale code for each block from the decoding stage and estimating the quantiser scale code based on the video content is unreliable. Many known algorithms for this estimation also have a number of parameters and thresholds, which must be adjusted to optimise performance for a given image content. This is undesirable in real systems and leads to poor performance.

There therefore remains a requirement for a system that provides good concealment of the block edges without removing the remaining high frequency detail and which does not need the level of coefficient quantisation to be supplied or estimated.

It is an object of the present invention at least to ameliorate the aforesaid shortcomings in the prior art.

According to a first aspect of the present invention there is provided an apparatus for reducing blocking artefacts in a decompressed image signal.
comprising: a video signal input; delay means connected to the video signal input; block and image content edges detection means, comprising an edge detection function, connected to the video signal input in parallel to the delay means; image content edge and block edge discriminating means connected to an output of the block and image content edges detection means; block edge concealing means connected to outputs of the delay means and the image content edge and block edge discriminating means.

Conveniently, the edge definition function is one of a Sodel, Kirsch and pseudo-Laplace function.

Preferably, the block and image content edges detection means comprises a Laplacian of Gaussian filter.

Advantageously, the image content and block edges discriminating means comprises means for removing or attenuating the image content edges.

Conveniently, the image content and block edges discriminating means comprises means for removing local DC signal from a transform domain signal.

Alternatively, the image content and block edges discriminating means comprises means for non-linear orthogonal correlation.

Preferably, the image content and block edges discriminating means comprises means for separately discriminating between vertical and horizontal image content edges and vertical and horizontal block edges.

Advantageously, the block edge concealing means comprises means for locating a nearest profile to a pel indicating a block edge transition and changing a value of the pel proportionally to a size of the transition and a distance of the pel from the transition to produce an error correcting signal and adding means for adding the error correcting signal to a delayed version of the decompressed video signal output from the delay means.

Advantageously, the apparatus further comprises a pre-processing stage arranged to determine an average size of block edge transitions in an image and to determine from the average size a threshold size of transition above which edges are not removed, and to output a corresponding threshold signal.
Preferably, the pre-processing stage is arranged to determine sizes of block edge transitions over at least one portion of an image.

Conveniently, the pre-processing stage comprises a Laplacian of Gaussian filter to detect horizontal edges.

Advantageously, the pre-processing stage comprises counting means arranged to count lines of a video image to determine locations where blocking edges may be expected from a known blocking size and to determine sizes of edge transitions only at those locations.

Preferably, the block and image content edges detection means comprises means for separately detecting horizontal and vertical edges.

Advantageously, the apparatus comprises:

a. block edge and image edge detection means arranged to output a vertical edge location signal and a horizontal edge location signal;

b. image horizontal down-sampler means arranged to receive and to down-sample the vertical edge location signal using a previously encoded resolution of the decompressed image signal;

c. image and block vertical edge discriminating means connected to an output of the down sampler arranged to remove or conceal the vertical image edges;

d. vertical edge transformation means for locating a nearest profile to a pel indicating a block vertical edge transition and determining a vertical edge error correcting signal for changing a value of a pel proportional to a size of the transition and a distance of the pel from the transition;

e. image horizontal up-sampler means connected to an output of the vertical edge transformation means arranged to up-sample the vertical edge error correcting signal;

f. image content and block horizontal edge discriminating means connected to receive the horizontal edge location signal and to delete or conceal the horizontal image edges;
g. horizontal edge transformation means for locating a nearest profile to a pel indicating a block horizontal edge transition and determining a horizontal edge error correcting signal for changing a value of a pel proportionally to a size of the transition and a distance of the pel from the transition;

h. adding means for adding the up-sampled vertical error correcting signal and the horizontal edge error correcting signal to form a combined error correcting signal; and

i. subtracting means to subtract the combined error correcting signal from a delayed version of the decompressed video signal output from the delay means.

According to a second aspect of the invention, there is provided a method of reducing blocking artefacts in an image compression system comprising the steps of: inputting a video signal; detecting block and image content edges with an edge detection function; discriminating between image content and block edges; and concealing the block edges.

Conveniently, the step of detecting block and image content edges comprises using a Sodel, Kirsch or pseudo-Laplace function.

Preferably, the step of detecting block and image content edges comprises using a Laplacian of Gaussian filter.

Advantageously, the step of discriminating between image content and block edges comprises removing or concealing the image content edges.

Conveniently, the step of discriminating between image content and block edges comprises local DC signal removal from a transform domain signal.

Alternatively, the step of discriminating between image content and block edges comprises non-linear orthogonal correlation.

Preferably, the step of discriminating between image content and block edges comprises separately discriminating between vertical and horizontal edges.

Advantageously, the step of concealing the block images comprises locating a nearest profile to a pel indicating a block edge transition and changing a value of...
the pel proportionally to a size of the transition and a distance of the pel from the transition.

Advantageously, the method comprises a pre-processing step of determining an average size of block edge transitions in an image and determining from the average size a threshold size of transition above which edges are not removed.

Preferably, determining an average size of block edge transitions comprises determining sizes of block edge transitions over at least one portion of an image.

Conveniently, the pre-processing step comprises using a Laplacian of Gaussian filter to detect horizontal edges.

Advantageously, the pre-processing step comprises counting lines of a video image to determine locations where blocking edges may be expected from a known blocking size and determining sizes of block edge transitions only at those locations.

Preferably, the step of detecting block and image content edges comprises separately detecting horizontal and vertical edges.

Advantageously, the method further comprises: detecting locations of vertical and horizontal block and image edges and generating a vertical edge location signal and a horizontal edge location signal; down-sampling the vertical edge location signal using a previously encoded resolution of the video signal; discriminating between vertical image edges and vertical block edges using the down sampled signal to form a vertical edge correcting signal; up-sampling the vertical edge correcting signal using the previously encoded resolution of the video signal to form an up-sampled vertical edge correcting signal; discriminating between horizontal image edges and horizontal block edges to form an horizontal edge correcting signal; and combining the vertical and horizontal edge correcting signals with a delayed version of the input video signal to reduce blocking artefacts.

Conveniently, the step of forming a vertical or horizontal edge correcting signal comprises locating a nearest block edge transition to a pel and forming an edge correcting signal arranged to change a value of the pel proportional to a size of the transition and a distance of the pel from the transition.
According to a third aspect of the invention, there is provided a computer program product comprising code means for performing all the steps of the method described above when the program is run on one or more computers.

According to a fourth aspect of the invention there is provided a computer program product as described above embodied by a computer storage medium.

The invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a graphical representation of a quantised 'blocked' surface;
Figure 2 is a schematic diagram of an embodiment of a basic system for removing blocking artefacts according to the invention;
Figure 3 is logical scheme of data flow in a Laplacian of Gaussian (LoG) filter with merged output suitable for use in the invention;
Figure 4 is a schematic diagram of the system of Figure 2 using the LoG filter of Figure 3;
Figure 5 is schematic diagram of the system of Figure 4 using a LoG filter with separated data sets for vertical and horizontal edges;
Figures 6a and 6b are representations of data sets h(x,y) and d(x,y) of Figure 4 with discrimination by localised DC removal;
Figures 7a and 7b are representations of data sets h(x,y) and d(x,y) of Figure 4 with discrimination by orthogonal correlation;
Figure 8 is a schematic diagram of an exemplary embodiment of a system according to the invention;
Figure 9 is a schematic diagram of detail of the measurement system of the system of Figure 8;
Figure 10 is a graphic representation of block step size information gathered in the measurement system of Figure 9
Figures 11a and 11b are representations of data sets d(x,y) and t(x,y) of Figure 5;
Figure 12a is a graphical representation of the data from Figure 1:
Figure 12b is a graphical representation of a version of the data of Figure 12a with a blocking artefact correction applied according to the invention.

Figure 13a is a graph representing an ideal edge in the transform domain;

Figure 13b is a graph representing an up-sampled edge;

Figure 14 is a schematic diagram of a system according to the invention for removal of blocking artefacts using a Laplacian of Gaussian filter with separated data sets with a down sampler and an up sampler;

Figure 15 is a source image with blocking artefacts;

Figures 16a and 16b are magnified portions from the source image of Figure 15;

Figures 17a and 17b are composites of data sets h₁ & h₂ transform domain signals of the magnified portions of Figures 16a and 16b respectively;

Figures 18a and 18b are the data sets of Figures 17a and 17b horizontally down sampled;

Figures 19a and 19b are the resultant corrected magnified portions of Figures 16a and 16b as produced with the system of Figure 2;

Figures 20a and 20b shows a resultant magnified image portions of Figures 16a and 16b corrected with the system of Figure 14;

Figure 21a shows the source image of Figure 15 corrected with the system of Figure 2; and

Figure 21b shows the source image of Figure 15 corrected with the system of Figure 14.

In the Figures like reference numerals denote like parts.

Figure 2 shows an embodiment 200 of the system of the invention in a basic form.
The system comprises in series an edge detector function 21, having an input 20 and an output 22 to a detail discrimination function 23 having an output 24 to a transformation function 25. An output 26 of the transformation function 25 and a delayed version 27 of a video signal input at the input 20 are both input to a subtract/add function 28 having an output 29.

Video information with block artefacts enters the system at the input 20 and is processed with the edge detection function 21. This can be implemented by one of a number of known methods such as, for example, Sobel, Kirsch or pseudo Laplace.

The output of the edge detector function 21 is a false image map 22 showing all the edges in the image. This 'edge map' will have different attributes dependent upon the algorithm chosen for the edge detection function 21, but will in general contain information on the block edges as well as variation in the original image from the content of the picture.

A next step in processing requires that information relating to the image content in the edge map 22 be removed by means of a post-processing step, or detail discrimination function 23. This attenuates or removes edges that are part of the image content and are not related to the block edges. This leaves the block edges to dominate.

A post-processed version of the edge map 24 is passed to the transforming operation 25 where the information contained is transformed into a correction signal 26. This signal 26 is then subtracted from, or added to, a delayed version 27 of the original video signal applied at input 20, which has been subjected to an appropriate video delay by a delay device (not shown) by an adder/subtractor 28. The output 29 of the subtract/add function 28 is a corrected, de-blocked video signal.

The purpose of the detail discrimination function 23 is to attenuate or remove image detail edges in the data stream 22 and the nature and function of the detail discriminator depends on a representation of each form of edge in the data stream 22, which varies according to the implementation of the edge detector function 21.
Again, a form and function of the transformation function 25 is governed by
the representation of edges in the data stream 24 output from the detail
discrimination function 23.

It is advantageous that an edge detection function 21 is chosen from the
available methods with the following properties. Firstly it should be immune, as
far as possible, to noise in the source image since this could cause edges to be
erroneously detected all over the field of data. Secondly the function should
represent the position of the edge unambiguously and with some degree of
precision. Thirdly the function should be easy to implement in that the number of
calculations and the form of the mathematics should be able to be implemented in
either software or hardware at a needed data rate. Finally it is advantageous if the
output 22 of the edge detector 21 is output to separate data streams for horizontal
and vertical edge information. This separation of information makes easier post-
processing of the data 24 output from the detail discrimination function.

The edge detector sub-system

There are a number of candidates from the available choices that fit these
requirements. For simplicity only one of these, the Laplacian of Gaussian filter, is
considered herein.

The Laplacian of Gaussian function, or LoG Filter, combines a two-
dimensional second derivation of the surface function with a noise reducing
smoothing by a Gaussian low-pass filter. A zero crossing in a final convolution
result represents edge pels.

If \( f(x,y) \) is an incoming image, \( k \) is a window size and \( h(x,y) \) is an outgoing
edge map then the two stage convolution is shown in equation 1.
**Equation 1 - The LoG function**

\[ u_1(x, y) = \sum_{i=-k}^{k} f(x+i, y) c_1(\text{abs}(i)) \]

\[ U_2(x, y) = \sum_{i=-k}^{k} \Lambda x + i, y) c_2(\text{abs}(i)) \]

\[ h_1(x, y) = \sum_{j=-k}^{k} u_1(x, y + j) c_2(\text{abs}(j)) \]

\[ h_2(x, y) = \sum_{j=-k}^{k} u_2(x, y + j) c_1(\text{abs}(j)) \]

\[ h(x, y) = n(x, y) + h_2(x, y) \]

where the coefficient sets \( C_1 \) and \( C_2 \) are the Laplacian and Gaussian coefficients and satisfy the conditions set out in equation 2.

**Equation 2 - The coefficient set conditions**

\[ C_1 = \sum_{i=-k}^{k} c_1(i) = 0 \]

\[ C_2 = \sum_{i=-k}^{k} c_2(i) = l \]

Equations 3 & 4 show derivations of the \( C_1 \) and \( C_2 \) sets. In both cases \( \sigma^2 \) denotes the Gaussian kernel size, i.e. the window size.

**Equation 3 - Derivation of the coefficient set \( C_1 \)**

\[ C_1(i, j) = \left( 2 - \frac{i^2 + j^2}{\sigma^2} \right) e^{-\frac{j^2 + j^2}{2\sigma^2}} \]

**Equation 4 - Derivation of the coefficient set \( C_2 \)**

\[ C_2(U) = e^{\frac{j^2 + j^2}{2\sigma^2}} \]

When using the LoG filter it is advantageous to use intermediary vertical and horizontal data sets \( h_1 \) and \( h_2 \) since post-processing of separated vertical and horizontal sets is less complex than working on a merged data set \( h \).

A system 400 employing the LoG filter is shown in Figure 4 with an edge detector function 41 embodied as a LoG filter. A data set 42 output from the LoG filter 41 is now \( h(x, y) \) from the LoG output as illustrated in Figure 3. Output 24
from the discrimination function is now labelled $d(x,y)$ to clarify the discriminator functions below.

In the embodiment of Figure 4, the edge discrimination function 23 is still working on a two dimensional, or merged, data set. This can be a disadvantage as the merged data set makes the discrimination task more complex, with more cases to consider. Since the separated data sets are available within the LoG algorithm it is advantageous to employ them.

Figure 5 shows a modified system 500 with the internal data sets, $h_1$ and $h_2$ employed. Figure 5 shows the LoG filter outputs 51, 52 as two data sets, $h_1$ and $t_{a2}$, where $h_1$ contains information on the vertical edges, and $h_2$ the horizontal edges.

The system 500 illustrated in Figure 5 has two parallel discrimination functions 53, 54, a first discrimination function 53 working on a first sub-set of data $h_1(x,y)$ representing vertical edges and a second discrimination function 54 working on a second sub-set of data $h_2(x,y)$ representing horizontal edges. The post-processed respective output data sets 55, 56 are transformed into respective correction signals by two parallel transformation functions 57, 58, which may be identical to each other, or may vary in operation in order to apply different responses to horizontal and vertical block edges.

The respective data sets $t_1(x,y)$, $t_2(x,y)$ output 591, 592 from the transformation functions 57, 58 contain separated correction data for the horizontal and vertical data sets respectively, which are summated to form an output 593 which is a complete correction set $t(x,y)$.

A subtractor 28 is used, as in the system 200 illustrated in Figure 2, to apply the correction set $t(x,y)$ to the delayed video signal 27 to form the output 29 of the system 500.

**The discriminator sub-system**

There are many methods available to implement the block edge / image detail discriminator 23; 53, 54.

One method that complements the system shown in Figure 4 is a local DC removal technique. This technique is based on the premise that much of the image detail is of lower spatial frequency than the block edges. The method involves
calculating a localised mean of levels and subtracting the localised mean from the pel under operation.

Equation 5 - Discrimination by localised DC removal

\[
k = \frac{n-1}{2}
\]

\[
d(x, y) = h(x, y) - \sum_{j=-k}^{k} \sum_{i=-k}^{k} h(x+i, y+j)
\]

Figures 6a and 6b are representations of data sets h(x,y) and d(x,y) before and after discrimination by localised DC removal, respectively. Thus Figures 6a and 6b show false image maps that diagrammatically represent data sets h(x,y) and d(x,y). The image of Figure 6a shows output h(x,y) of the LoG filter and shows both block edges and image detail. The image of Figure 6b shows the data set d(x,y) with n=3 and the reduction in picture detail and enhancement of block edges can be seen.

An alternative discriminator function is a non-linear orthogonal cor-elation function shown in equation 6. With this technique an assessment of the information is made at a point of operation as to the likelihood that the information represents an edge that may be a block edge. This is then correlated orthogonally to confirm a matching profile.
Equation 6 — Discrimination by non-linear orthogonal correlation

\[
d(x,y) = \begin{cases} 
0 & \text{if } \text{Sum}_A < N \& \text{Sum}_B < N \\
\sum_A < N & \text{elsewhere}
\end{cases}
\]

Where \( n \) is the correlation range, \( N \) is the degree of correlating occurrences in \( n \) and \( m \) is the margin of correlation.

Figures 7a and 7b show representations of data sets \( h(x,y) \) and \( d(x,y) \) before and after discrimination by such orthogonal correlation, respectively.

Finally, if the edge detection function used is the LoG filter then the centre of an edge can be identified by a zero crossing in the transform domain. This means that each point in the edge map can be assessed as to the profile of the pulse and the orthogonal coherence of the zero crossing point.

Example pseudo code for this is as follows.

```
FOR y = 0 TO Y_MAX
  FOR x = 0 TO X_MAX-1
    IF ( Pulse_Profile( h_g(x,y), h_g(x+1,y) ) > Profile_Threshold )
      Current_Zero_Crossing_Point = Assess_ZC_Point ( h_g(x,y) , h_g(x+1,y) )
      FOR z = +cr TO -cr
        IF ( (Assess_ZC_Point ( h_g(x,y+z), h_g(x+1,y+z) )
            - Current_Zero_Crossing_Point ) > Crossing_Threshold )
          Other_ZC_Points [z] = 1
        ELSE
          Other_ZC_Points [z] = 0
      END_IF
    END_IF
  END_FOR
END_FOR
```
the function \text{Pulse\_Profile} returns a fractional value representing a
correlation of the information at a current point of operation to a profile of an
ideal edge in the transform domain;
the function \text{Assess\_ZC\_Point} returns a fractional value to indicate a
position of a matched zero crossing relative to the current point of operation;
the function \text{Assess\_Other\_ZC\_Points} returns a Boolean decision as to
whether an appropriate group of samples show correlation of a matching edge.
This involves assessing sample information orthogonally from the point of
operation over an appropriate range, CR, and filtering the decision on a threshold
of matches adjacent to the sample under operation. This becomes increasingly
important as CR rises; and
the function \text{Pulse\_Profile} could take the form of the following equation.

\textbf{Equation 7 - Possible form for the assessment of edges}

\[
Score = e^{-M \left( \frac{\sqrt{a^2 + b^2}}{2} \right)}
\]

Where M is a constant.

The function \text{Assess\_ZC\_Point} could take the form shown in Equation 8.
This holds while the pulse profile returns a high value and the sample pair forms a
bipolar relationship.

\textbf{Equation 8 - Possible form for the assessment of zero crossing}

\[
\begin{align*}
\text{Zero\_Crossing} &= \left[ -\left( \frac{a + b}{2} \right) \right] + 0.5 \\
\end{align*}
\]

Where a and b are samples under operation.

Edge detection and discrimination methods can be unreliable in that real
edges can occasionally be confused with those resulting from block boundaries
and so any means of discriminating between these alternatives is valuable. A
method of limiting the unwanted artefacts by measuring and processing statistics from the image has been found and this has lead to an automation of the system that adjusts to the image content and degree of impairment. This limits the artefacts induced by this process.

By examining a size of the transition across known block edges, a distribution of occurrence can be generated and used to set a limit for the whole image as to the statistical size of the impairment step.

Once this frequency of occurrence of a given step size has been measured a limit can be established for the main de-blocking algorithm whereby a correction surface is not generated even if the profile and edge coherence metrics are met.

Figure 8 shows an exemplary embodiment of a system according to the invention. When processing an image in a computer system the measurement can be made on the image immediately before it is processed. In a physical implementation part or the entire image must undergo examination before the de-blocking algorithm can be provided with a meaningful threshold. For this reason Figure 8 shows a measurement system 85, 88, an image delay element 81 and a de-blocking system 500 as illustrated in Figure 5.

In Figure 8, a video signal with block artefacts enters at input 10. A measurement system 85 measures a size of block edge transitions over the image or some section of it. This statistical information 86 is passed to threshold decision logic 88 that analyses the edge transition size and decides on a threshold of step size above which an edge will be ignored. Output 89 from the threshold decision function 88 is passed to the previously described de-blocking system 500, which is illustrated in Figure 5. Processed video 84 leaves the system which is equivalent to output 29 in Figure 5. The input 10 of Figure 8 is equivalent to the input 20 in Figure 5. The compensating delay 81 is used to ensure that the image output to the block artefact removal function 500 is co-timed with the output 89 of the decision of threshold decision function 88.

An optional input 87 to the threshold decision function 88 can be used to control or bias the decision-making process of the threshold decision function 88.

Figure 9 shows the detail of the measurement system block 85 of the system illustrated in Figure 8.
In Figure 9 a Laplacian of Gaussian filter is used in a similar fashion to
the de-blocking filter used in the edge detection function 41. The two outputs of
the filter, the horizontal edges 92 and the vertical information 93 are output. The
vertical edges 93 are discarded as unneeded but the horizontal edges 92 are
examined in a similar fashion to the de-blocking filter; this is because the vertical
edges are extremely difficult to discern especially when the video has been
interpolated in a previous stage. Horizontal edges are more stable due to their
dependence on the video line structure and are thus more reliably found.

Vertical count block 91 counts the lines of video as they pass through the
system. This count 94 is passed to a position decoder 95, which outputs to
amplitude statistics gatherer block 97 points in the image when a block edge
might be expected to form based on the block size of the image compression
algorithm.

Amplitude statistics gatherer block 97 receives the input from block 95 and
if profile comparator block 96 indicates a presence of an edge at that position,
then the amplitude of that edge is recorded, for example in a frequency of
occurrence graph as shown in Figure 10.

This process gives a distribution of the measured amplitude of block edges
in the image by filtering to spatial positions where edges will commonly occur
and confirming their presence by metrics that profile the edges.

Only horizontal edges are sought in this system. This is because the
positions of the edges are more predictable since there is usually no issue of sub-
sampling for encoding in the vertical direction.

Once a significant sample set has been accrued the contents of the amplitude
distribution can be processed. This period may be over the entire image or may be
segmented to sub-regions of the image to allow variation within each image. The
assessment of these statistics aims to set a cutoff point of amplitude whereby large
edges are assumed to belong to image content and are therefore preserved in de-
blocking. Figure 10 shows an example of how this information may be
represented graphically.

Figure 10 is a graph showing a line 101 depicting a typical data set from the
system. The horizontal axis maps the size of the step and the vertical axis
represents the number of occurrences of that size in this image. The axes labels and numbering are arbitrary in this example.

In most compressed images the amplitude of the block edges is predominantly small, leading to a higher curve on the left hand side. Although large block edges can occur, in most images peaks on the right hand side of the curve are caused by image content and detail that has wrongly been identified as block edges.

This information can be processed by means such as smoothing, low pass filtering or curve matching and an upper threshold established for the step size of the blocks.

**The transformation function sub-system**

The function of the transformation function block 25; 57, 58 is to transform a map 24; 55, 56 of block edges into a correction signal t(x,y). The action of this module will vary according to the edge detector algorithm used, since the transform must match the format of data the edge detector outputs.

If the LoG filter is used then the following algorithm is suitable for the transformation.

Working on the separated data sets, d_1 and d_2, the nearest significant profile that indicates a block edge transition is found. When found, the level of the sample under operation is changed to a value proportional to the size of the transition and the distance from that edge. Figure 11 demonstrates an example result of such a process. That is, Figures 11a and 11b show representations of data sets d(x,y) and t(x,y) from Figure 5, respectively.

The image of Figure 11a shows a sample block, identified in the post-processed data set d(x,y). This false image map shows block edges around almost all of the four sides of the block represented by a deviation from mid grey, (which represents zero).

Referring to Figure 11b, after processing the correction data map t(x,y) shows a gradient of intensity falling from top left 111 to top right 112 and from top left 111 to bottom left 113. This implies that the top left portion of this block
will be darkened in the corrected image and the right side will be lightened. Since the bottom left is mid grey then little or no correction will be applied here.

Hence the incoming video has the local flattened surface tilted in two dimensions to conceal the block edges. Referring back to Figure 1 if this process is applied to a two-dimensional graph the corrected image is modified from that represented in Figure 12a, which shows a representation of the data from Figure 1 to a version in Figure 12b of the same data with the proposed correction applied.

In summary, the invention has the advantages of removing blocking artefacts without requiring knowledge of the quantiser scale code, nor does it rely on an assumption that block edges are only present on a fixed grid. Further there are no complex thresholds that require optimisation for the source material.

One issue with broadcast feeds is that an image is frequently encoded in the compression domain with a horizontal resolution lower than the display resolution. This is done as a further bit-saving measure as the reduced horizontal bandwidth contains less information to be encoded.

While block edges still exist in the sub-sampled domain, when they are up-sampled to the original resolution for display the edge becomes more diffuse and less well defined.

Referring to Figure 5, a clean edge $hi(x,y)$, $h2(x,y)$ in the transform domain, at outputs 51 & 52, would be represented by a symmetrical bi-polar pulse as shown in graph 31 of Figure 13a. An edge that has been up-sampled for display produces a pattern similar to the graph 32 of Figure 13b. Instead of a clean bi-polar pulse, ringing and distortion can be seen.

This leads to two issues with the de-blocking system in Figure 5, first it is more difficult reliably to recognise an edge which is distorted and secondly it is difficult to create a matching correction signal to compensate and conceal the distorted edge. Widening the matching case when looking for edges can compensate for the first of these problems. However, this has a disadvantage that more picture data will be incorrectly identified as block edges, which in turn leads to more artefacts being induced in the output. The second issue is more difficult to compensate for.
Referring to Figure 14, there is illustrated an enhancement to the system of Figure 5, in which the transform domain signal $t_{14}(x,y)$ from the Laplacian of Gaussian filter 41 that contains information on the vertical edges i.e. edges encountered while traversing the image horizontally, is down sampled by an image horizontal down-sampler 141 from a display resolution to a previous encoded resolution (PER) used by a compression system preceding this system.

This has the effect of sharpening the transform domain representation of block edges and allows their detection using the same metrics as full resolution vertical and horizontal edges without compromising a matching stringency.

Thus, referring to Figure 14, a sub-sampled transform domain 411 output from the image horizontal down-sampler 141 is passed to a discriminator 221 as in Figure 5 and the transformation of the discriminated signal by the transformation function 231 to form data set 245 proceeds. Once this signal is prepared an up-sampler 142 turns the lower resolution correction signal into a full resolution signal $t_i(x,y)$ which now contains a correction signal suitable for application to a delayed video signal 27 which is derived by passing the video signal at input 20 through a video delay 201.

In order to demonstrate the problem and the effectiveness of the proposed system a number of images are presented by way of example.

In order to process the image appropriately the previous encoded resolution, PER 125 is input to the image horizontal down-sampler 141 and the image horizontal up-sampler 142. The PER is a horizontal resolution used in the proceeding MPEG encoding process that caused the blocking artefacts under operation.

Figure 15 shows an example image suitable for processing with a de-blocking system. The highlighted areas 151, 152 show from where magnified example areas in Figures 16a and 16b are taken, respectively.

The image of Figure 15 has suffered blocking artefacts by being MPEG-encoded at a moderately high level of quantisation. The display resolution of the image is 720 pels wide but when the image was MPEG-encoded this resolution was reduced to 544 pels to save bit rate.
Figures 16a and 16b show two sections of the image highlighted in Figure 15 magnified for clarity and both clearly show blocking artefacts to be removed.

Figures 17a and 17b show the two magnified sections of the image of Figures 16a and 16b after being transformed by the Laplacian of Gaussian operator. The transform domain has been represented here as a false image map by lifting the zero value to mid grey. Hence a negative deviation is represented by a darker pel and a positive deviation by a brighter than mid grey value.

The data sets h1 & h2 have been composted in these images to compare and contrast the horizontal and sub-sampled vertical edges.

In both the false image maps of Figures 17a and 17b horizontal edges can be seen to be clean, bi-polar pulses, as represented by a run of mid grey pels followed by a darker then proportionally lighter pel before returning to mid grey.

The vertical edges show a more complex, less well-defined shape as exemplified in the graph of Figure 13b. These edges often show an indeterminate rate of rise and fall without a focused centre point.

Figures 18a and 18b show data sets from the output 411 of the image horizontal down-sampler 141 of Figure 14. Here the data set containing the vertical edge information has been down sampled to 544 pels. The false image maps shown are similar to those from Figures 17a and 17b but for clarity the information for the horizontal edges has been omitted, leaving only the vertical edges of interest.

The representations of the edges in Figures 18a and 18b have sharpened and become far more symmetrical bi-polar pulses. This greatly aids the discrimination stage 221 and the transformation stage 231 of the apparatus illustrated in Figure 4.

Figures 19a and 19b show the areas under consideration after processing with the system of Figure 5. This data comes from the output 29, i.e. without the enhancement to the system illustrated in Figure 14. Not all of the block edges have been concealed and that a residual of all the block edges has remained despite the processing.

Figures 20a and 20b show resultant corrected image portions at output 28 in Figure 14. These images have been processed by the enhanced system and show a
significant improvement in the performance of the block edge concealment. That is, Figures 20a and 20b show a substantially higher rate of block edge recognition and concealment thanks to the enhanced system of Figure 14.

This is shown over a larger portion of the image in Figures 21a and 21b where the image of Figure 21a is that from output 29 of the system of Figure 5 and does not benefit from the enhancement. The image of Figure 21b is from output 28 of the system shown in Figure 14 and benefits from the enhancement.

It can be seen that the enhanced system recognises and conceals more block edges that the basic system.
CLAIMS

1. An apparatus for reducing blocking artefacts in a decompressed image signal comprising:

   a. a video signal input;

   b. delay means connected to the video signal input;

   c. block edge and image content edge detection means, comprising an edge detection function, connected to the video signal input in parallel to the delay means;

   d. image content edge and block edge discriminating means connected to an output of the block edge and image content edge detection means;

   e. block edge concealing means connected to outputs of the delay means and the image content edge and block edge discriminating means.

2. An apparatus as claimed in claim 1, wherein the edge detection function is one of a Sodel, Kirsch and pseudo-Laplace function.

3. An apparatus as claimed in claims 1 or 2, wherein the block and image content edges detection means comprises a Laplacian of Gaussian filter.

4. An apparatus as claimed in any of the preceding claims, wherein the image content and block edges discriminating means comprises means for removing or attenuating the image content edges.

5. An apparatus as claimed in any of the preceding claims, wherein the image content and block edges discriminating means comprises means for removing local DC signal from a transform domain signal.

6. An apparatus as claimed in any of the preceding claims, wherein the image content and block edges discriminating means comprises means for non-linear orthogonal correlation.

7. An apparatus as claimed in any of the preceding claims, wherein the image content and block edges discriminating means comprises means
for separately discriminating between vertical and horizontal image content edges and vertical and horizontal block edges.

8. An apparatus as claimed in any of the preceding claims, wherein the block edge concealing means comprises means for locating a nearest profile to a pel indicating a block edge transition and changing a value of the pel proportionally to a size of the transition and a distance of the pel from the transition to produce an error correcting signal and adding means for adding the error correcting signal to a delayed version of the decompressed video signal output from the delay means.

9. An apparatus as claimed in any of the preceding claims, comprising a pre-processing stage arranged to determine an average size of block edge transitions in an image and to determine from the average size a threshold size of transition above which edges are not removed, and to output a corresponding threshold signal.

10. An apparatus as claimed in claim 9, wherein the pre-processing stage is arranged to determine sizes of block edge transitions over at least one portion of an image.

11. An apparatus as claimed in claims 9 or 10, comprising a Laplacian of Gaussian filter to detect horizontal edges.

12. An apparatus as claimed in any of claims 9 to 11, comprising counting means arranged to count lines of a video image to determine locations where blocking edges may be expected from a known blocking size and to determine sizes of edge transitions only at those locations.

13. An apparatus as claimed in any of the preceding claims, wherein the block and image content edges detection means comprises means for separately detecting horizontal and vertical edges.

14. An apparatus as claimed in claim 13: comprising

  a. block edge and image edge detection means arranged to output a vertical edge location signal and a horizontal edge location signal;
b. image horizontal down-sampler means arranged to receive and to
down-sample the vertical edge location signal using a previously
encoded resolution of the decompressed image signal;

c. image and block vertical edge discriminating means connected to
an output of the down sampler arranged to remove or conceal the
vertical image edges;

d. vertical edge transformation means for locating a nearest profile to
a pel indicating a block vertical edge transition and determining a
vertical edge error correcting signal for changing a value of the pel
proportional to a size of the transition and a distance of the pel
from the transition;

e. image horizontal up-sampler means connected to an output of the
vertical edge transformation means arranged to up-sample the
vertical edge error correcting signal;

f. image content and block horizontal edge discriminating means
connected to receive the horizontal edge location signal and to
delete or conceal the horizontal image edges;

g. horizontal edge transformation means for locating a nearest profile
to a pel indicating a block horizontal edge transition and
determining a horizontal edge error correcting signal for changing
a value of the pel proportionally to a size of the transition and a
distance of the pel from the transition;

h. adding means for adding the up-sampled vertical error correcting
signal and the horizontal edge error correcting signal to form a
combined error correcting signal; and

i. subtracting means to subtract the combined error correcting signal
from a delayed version of the decompressed video signal output
from the delay means.

15. A method of reducing blocking artefacts in an image compression
system comprising the steps of:

a. inputting a video signal;
b. detecting block and image content edges using an edge detection function;

c. discriminating between image content edges and block edges;

d. concealing the block edges.

16. A method as claimed in claim 15, wherein the step of using an edge detection function comprises using one of a Sobel, Kirsch and pseudo-Laplace function.

17. A method as claimed in claims 15 or 16, wherein the step of detecting block and image content edges comprises using a Laplacian of Gaussian filter.

18. A method as claimed in any of claims 15 to 17, wherein the step of discriminating between image content edges and block edges comprises removing or concealing the image content edges.

19. A method as claimed in any of claims 15 to 18, wherein the step of discriminating between image content edges and block edges comprises local DC signal removal from a transform domain signal.

20. A method as claimed in any of claims 15 to 18, wherein the step of discriminating between image content edges and block edges comprises non-linear orthogonal correlation.

21. A method as claimed in any of claims 15 to 20, wherein the step of discriminating between image content edges and block edges comprises separately discriminating between vertical and horizontal edges.

22. A method as claimed in any of claims 15 to 21, wherein the step of smoothing the block images comprises locating a nearest profile to a pel indicating a block edge transition and changing a value of the pel proportionally to a size of the transition and a distance of the pel from the transition.

23. A method as claimed in any of claims 15 to 22 comprising a pre-processing step of determining an average size of block edge
transitions in an image and determining from the average size a
threshold size of transition above which edges are not removed.

24. A method as claimed in claim 23, wherein determining an average size
of block edge transitions comprises determining sizes of block edge
transitions over at least one portion of an image.

25. A method as claimed in claims 23 or 24, comprises using a Laplacian
of Gaussian filter to detect horizontal edges.

26. A method as claimed in any of claims 23 to 25, comprising counting
lines of a video image to determine locations where blocking edges
may be expected from a known blocking size and determining sizes of
block edge transitions only at those locations.

27. A method as claimed in any of claims 15 to 26, wherein the step of
detecting block and image content edges comprises separately
detecting horizontal and vertical edges.

28. A method as claimed in claim 27 comprising:

   e. detecting locations of vertical and horizontal block and image
edges and generating a vertical edge location signal and a
   horizontal edge location signal;

   f. down-sampling the vertical edge location signal using a previously
   encoded resolution of the video signal;

   g. discriminating between vertical image edges and vertical block
   edges using the down sampled signal to form a vertical edge
correcting signal;

   h. up-sampling the vertical edge correcting signal using the
   previously encoded resolution of the video signal to form an up-
sampled vertical edge correcting signal;

   i. discriminating between horizontal image edges and horizontal
   block edges to form an horizontal edge correcting signal; and
j. combining the vertical and horizontal edge correcting signals with a delayed version of the input video signal to reduce blocking artefacts.

29. A method as claimed in claim 28, wherein the step of forming a vertical or horizontal edge correcting signal comprises locating a nearest block edge transition to a pel and forming an edge correcting signal arranged to change a value of the pel proportional to a size of the transition and a distance of the pel from the transition.

30. A computer program product comprising code means for performing all the steps of the method of any of claims 15 to 29 when the program is run on one or more computers.

31. A computer program product as claimed in claim 30 embodied by a computer storage medium.
Figure 3

Figure 4
Figure 5

Figure 6a

Figure 6b
Figure 8

Figure 9
Figure 11b

Figure 12a

Figure 12b
Fig. 15