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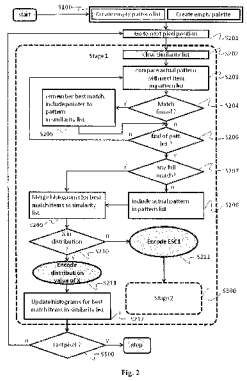


Fig. 2

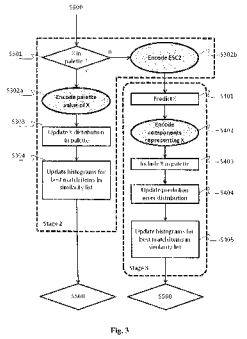


Fig. 3

(57) Abstract: The present invention relates to a method and a system for efficiently compressing images by estimating contextual probability distributions based on virtually all samples processed up to a current position in the image. The method comprises encoding a distribution symbol of the property vector X from a distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel, when the property vector X of the respective pixel occurred in any of the contextual patterns that are identical or similar to the contextual pattern of the respective pixel; encoding a first stage exception handling symbol and a palette symbol of the respective property vector X of a dynamically generated palette of property vectors, when the respective property vector X of the respective pixel has not occurred in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel; and encoding a first stage exception handling symbol, a second stage exception handling symbol, and a representation of all components of the property vector X, when the property vector X has not occurred in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel and the property vector X is not found in the palette.

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Intra Compression of Screen Content based on Soft Context Formation

The present invention relates to a method and a system for efficiently compressing images, preferably for lossless compression of screen content, by estimating contextual probability distributions based on virtually all samples processed up to a current position in the image.

Among others, one challenge in data compression is to transmit or store a minimum number of bits per sample that should be as close as possible to the number of bits defined by the actual average information content. The actual average information content can generally be approximated by the contextual entropy. The challenge is generally that the optimal estimation of contextual symbol probabilities is a kind of artificial-intelligence problem and requires enormous computational efforts. Therefore, practical compression methods typically utilize some pre-knowledge about the data.

The research in lossless image compression has focused in the past either on natural images or on color-map images with up to 256 different colors. Natural images, such as photographs, show high correlation between the neighboring pixels and compression systems based on pixel-value prediction are most successful.

Images with graphical content are compressed with methods based on dictionary-based compression such as Lempel–Ziv–Welch (LZW) or LZ77. The repetition of sample combinations can also be efficiently handled via prediction by partial matching (PPM).

Regarding synthetic color-map images, the compression can be efficient, for example, based on a piece-wise constant model, or using a generalized context tree (GCT) algorithm with incomplete structure.

Little effort, however, has been made towards the lossless compression of those images which can neither be compressed efficiently with conventional predictive techniques, such as CALIC, JPEG-LS, JPEG2000, H.264/AVC, or high efficiency video coding (HEVC), nor with methods assuming repeating patterns in the data. As a vast portion of pictures found in the internet belong to this class of images, a dedicated compression system is indispensable. A great step towards optimal compression of these data is accomplished by using weighted context mixing. As this also concerns the compression of image sequences, there is rising

interest in the compression of so-called screen content. The HEVC standardization group has developed a respective dedicated extension.

It is an objective of this invention to provide a method and system for efficiently compressing such images by estimating contextual probability distributions based on virtually all samples processed up to a current position in the image.

Among others, it is a gist of the present invention that the distribution model is newly generated for each pixel and it is fed into a standard multi-level arithmetic coder together with the actual pixel value, enabling a coding close to the estimated contextual entropy.

This description uses a number of technical terms in addition or alternatively to the usual definition known to the skilled person. These terms have the following definitions in the context of some aspects of the invention:

A pixel has a position in the image indicated by a small letter and a property vector indicated by a capital letter. The property vector may have different elements, which are also referred to as values.

A template is a spatial arrangement of pixels, preferably neighbouring pixels to a specific pixel, which are taken into account for a specific processing step.

A pattern is a vector of numbers preferably taken from a template in a specific order.

A current or actual pattern is the pattern that is located at the current pixel position of the specific pixel.

A context is a plurality of patterns that are identical or similar to a specific pattern.

Contextual patterns are a plurality of patterns which occurred in a common, identical, and/or similar context. Said contextual patterns will be stored in a pattern list in some aspects of the invention, wherein the specific plurality is not a fixed plurality but may be newly compiled dependent on a current context and/or a similarity criterion in some aspects of the invention.

The method and system may also be applied in the framework of HEVC for the compression of screen content. The demands and requirements in screen-content coding have a broad

spectrum and are extremely diverse. Low costs and low latency are two major opponents of maximum compression, along with the request for flexibility, for example, in the presence of mixed content.

The method and system for compression according to the present invention focuses on maximum compression of synthetic data such as computer generated graphics, text, and screenshots. The method and system follows the approach of statistical compression and implements a two-step processing of modeling and coding.

In principle, the problem of ideal entropy coding is solved by arithmetic coding; however, the modeling of probabilities remains an objective for this invention. It is a further objective to reduce the computational complexity to a feasible order while providing an excellent compression performance.

The above objectives are among those achieved by the independent claims. The dependent claims relate to further aspects of the invention.

The method according to the present invention is computer-implemented. However, it is understood by the skilled person that there are also other ways of implementing the method according to the present invention.

Let $p(s_i)$ be the probability of symbol s_i, which may be the value of a pixel. Then $I(s_i) = -\log_2 [p(s_i)]$ [bit] is the information content associated with the symbol s_i. In practical applications, the probabilities are often not known in advance, but can be approximated by the relative frequency $n(s_i)/N$, if $n(s_i)$ is the count of symbol s_i and N is the total number of all s_i . The optimal coding of symbol s_i is achieved when the coding scheme outputs exactly $I(s_i)$ bits. The only known coding method, which can perform close to this optimum, is called arithmetic coding. Hereinafter only causal systems are considered.

Typically, the probability of a symbol at a specific pixel position is dependent on what happened in the past at previously encoded pixels, allowing for the probabilities to be approximated by $n(s_i \,|C)/N_C$ and $I(s_i \,|C) = -\log_2 [p(s_i \,|C)]$ [bit]. Wherein the variable C defines the context, i.e., the past of the occurrence of s_i, $n(s_i \,|C)$ is the frequency of s_i occurring in the context C, and N_C is the number representing how often the context C has

been observed up to the current position. If a symbol has to be encoded, its contextual probability $p(s_i|C)$ should be known. In images, there are dependencies between single pixel values and the contextual probability $p(s_i|C)$ is different from $p(s_i)$.

In an illustrative example, a grey-level image is considered with eight bits per pixel. The estimation of $p(s_i)$ is simple. The different symbols s_i ranging between 0 and 255 have to be counted and the frequencies $n(s_i)$ can be stored in a histogram with $2^8 = 256$ bins representing the distribution of all different s_i.

If a current pixel would be related to one of its neighbors, 256 contexts have to be considered and for each context a separate histogram has to be determined. All counts could be stored in a two-dimensional histogram with 256^2 bins. It is clear for the skilled person that the extension of the context to two or more adjacent pixels will become difficult. Another algorithm is then required which does not store all probabilities (or counts), but rather estimates the contextual probabilities in a more memory-efficient manner. This, however, leads to the dilemma in programming that an algorithm is either fast and memory consuming, or it requires little memory and is slow.

The context problem can be eased to a certain extent by mapping multi-level symbols to binary symbols where only a single bit is predicted based on context bits.

The present invention relates to a method for encoding an image, in particular for reducing the computational complexity for encoding the image, based on an optimal estimation of a distribution probability, wherein the method comprises encoding of at least one symbol for a property vector X of a respective pixel of a plurality of pixels in sequence based on contextual patterns formed by a plurality of neighboring pixels. The method comprises encoding a distribution symbol of the property vector X from a distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel, when the property vector X of the respective pixel has occurred in any of the contextual patterns that are identical or similar to the contextual pattern of the respective pixel. The method further comprises encoding a first stage exception handling symbol and a palette symbol of the respective property vector X of a dynamically generated palette of property vectors, when the respective property vector X of the respective pixel has not occurred in the contextual patterns that are identical or similar to the contextual pattern of the

respective pixel. The method further comprises encoding a first stage exception handling symbol, a second stage exception handling symbol, and a representation of all components of the property vector X, when the property vector X has not occurred in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel and the property vector X is not found in the palette.

Preferably, the similarity between two contextual patterns is determined based on the comparison of at least one threshold value with a modulus of a vector difference of the property vector of at least one pixel of the respective contextual pattern and a pixel in a corresponding position of the pattern referred to in the first list.

Preferably, a similarity value is calculated from the individual distance measures between property vectors in the corresponding positions in the respective patterns. Preferably, a similarity value is the count of positions in the contextual pattern which are similar to the corresponding positions in the other pattern.

Preferably, during the encoding of the image a first list is dynamically generated, which comprises references to patterns found in the image and further comprises for every respective pattern a histogram containing a distribution of all property vectors X which have occurred in the respective pattern during the scan, and wherein, when during the encoding of the respective pixel no corresponding pattern is found in the first list, the respective pattern is appended to the first list, wherein the patterns comprised in the first list patterns are not identical.

Preferably, the method further comprises the steps of updating the property vector distribution of the palette after the encoding of the first stage exception handling symbol and the palette symbol of the respective property vector X and updating a prediction error distribution after the encoding of the first stage exception handling symbol, the second stage exception handling symbol, and the prediction error.

Preferably, during the encoding of a respective property vector X a second list is dynamically and temporally generated, based on a calculated similarity value. Preferably, the second list comprises a reference to at least one contextual pattern of the first list being similar to the contextual pattern of the neighboring pixels of the respective pixel.

Preferably, the second list is empty when no similar pattern has been found to the contextual pattern of the neighboring pixels of the respective pixel.

Preferably, the method further comprises the step of updating the respective histograms of patterns referred to in the first list after the encoding of the respective property vector X.

Preferably, the method further comprises the step of updating the respective histograms of patterns referred to in the first list, based on the second list, after the encoding of the respective property vector X.

Preferably, the distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel is generated by merging the respective histograms of all items on the second list having a highest similarity value.

Preferably, a set of thresholds for each of the positions in the contextual pattern is determined based on image properties.

Preferably, the thresholds are variably adapted during the encoding.

Preferably, the method further comprises the step of reducing the number of items on the first and/or second list by deleting at least one pattern which is determined as not being relevant from the first list. Preferably, by deleting at least one pattern which is determined as not being relevant from the second list.

Preferably, the representation of all components of the property vector X is based on a prediction of the components and wherein for a first component a preferred prediction method is determined and the preferred prediction method is used to predict at least one further component.

Alternatively still preferably, the representation of all components of the property vector X is based on a prediction of the components and wherein for a first component a preferred prediction method is determined and the preferred prediction method is used to predict all further components.

In a preferred embodiment of the invention the number of neighboring pixels forming a contextual pattern is six or less.

The present invention also relates to a computer program product comprising one or more computer readable media having computer executable instructions for performing the steps of any of the aforementioned methods according to the present invention.

The present invention also relates to a system for encoding an image, in particular for reducing the computational complexity for encoding the image, based on an optimal estimation of a distribution probability. The system is configured to encode at least one symbol for a property vector X of a respective pixel of a plurality of pixels in sequence based on contextual patterns formed by a plurality of neighboring pixels. The system comprises: an encoding unit being configured to encode a distribution symbol of the property vector X from a distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel, when the property vector X of the respective pixel has occurred in any of the contextual patterns that are identical or similar to the contextual pattern of the respective pixel. The encoding unit is configured to encode a first stage exception handling symbol and a palette symbol of the respective property vector X of a dynamically generated palette of property vectors, when the respective property vector X of the respective pixel has not occurred in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel. The encoding unit is further configured to encode a first stage exception handling symbol, a second stage exception handling symbol, and a representation of all components of the property vector X, when the property vector X has not occurred in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel and the property vector X is not found in the palette.

Preferably, the system comprises means being configured to determine the similarity between two contextual patterns based on the comparison of at least one threshold value with a modulus of a vector difference of the property vector of at least one pixel of the respective contextual pattern and a pixel in a corresponding position of the pattern referred to in the first list.

Preferably, the system comprises means being configured to calculate a similarity value from the individual distance measures between property vectors in the corresponding positions in the respective patterns. Preferably, the system comprises means being configured to determine the similarity value by counting the positions in the contextual pattern which are similar to the corresponding positions in the other pattern.

Preferably, the system comprises means being configured to dynamically generate a first list during the encoding of the image, which comprises references to patterns found in the image and further comprises for every respective pattern a histogram containing a distribution of all property vectors X which have occurred in the respective pattern during the scan. Preferably, the system comprises means being configured to append to the first list the respective pattern when during the encoding of the respective pixel no corresponding pattern is found in the first list, wherein the patterns comprised in the first list patterns are not identical.

Preferably, the system comprises means being configured to update the property vector distribution of the palette after the encoding of the first stage exception handling symbol and the palette symbol of the respective property vector X. Preferably, the system comprises means being configured to update a prediction error distribution after the encoding of the first stage exception handling symbol, the second stage exception handling symbol, and the prediction error.

Preferably, the system comprises means being configured to dynamically and temporally generate a second list during the encoding of a respective property vector X, based on a calculated similarity value. Preferably, the second list comprises a reference to at least one contextual pattern of the first list being similar to the contextual pattern of the neighboring pixels of the respective pixel. Preferably, the second list is empty when no similar pattern has been found to the contextual pattern of the neighboring pixels of the respective pixel.

Preferably, the system comprises means being configured to update the respective histograms of patterns referred to in the first list after the encoding of the respective property vector X.

Preferably, the system comprises means being configured to update the respective histograms of patterns referred to in the first list, based on the second list, after the encoding of the respective property vector X.

Preferably, the system comprises means being configured to generate the distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel by merging the respective histograms of all items on the second list having a highest similarity value.

Preferably, the system comprises means being configured to determine a set of thresholds for each of the positions in the contextual pattern based on image properties.

Preferably, the system comprises means being configured to are variably adapted the thresholds during the encoding.

Preferably, the system comprises means being configured to reduce the number of items on the first and/or second list by deleting at least one pattern which is determined as not being relevant not been recently found to be similar from the first list, and/or by deleting at least one pattern which is determined as not being relevant with a similarity value smaller than the highest similarity value from the second list.

Preferably, the representation of all components of the property vector X is based on a prediction of the components and the system comprises means being configured to determine for a first component a preferred prediction method and the preferred prediction method is used to predict at least one further component.

Alternatively still preferably, the representation of all components of the property vector X is based on a prediction of the components and the system comprises means being configured to determine for a first component a preferred prediction method and the preferred prediction method is used to predict all further components.

Brief description of the drawings

The accompanying drawings, which are included to provide a further understanding of the invention, illustrate embodiments of the invention and together with the description serve to explain the principle of the invention.

In the drawings:

Fig. 1 shows an illustration of the formation of a contextual pattern of one embodiment of the method according to the invention,

Fig. 2 shows a block-diagram of one embodiment of the first stage of the method according to the invention, and

Fig. 3 shows a block-diagram of one embodiment of the second and third stage of the method according to the invention.

Detailed description of the invention

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings. In particular, the preferred embodiments of the present invention as described below refer to lossless compression of screen content. However, it is clear for the skilled person from the overall disclosure of the present invention that the invention is not limited thereto. The accompanying drawings illustrate exemplary embodiments of the present invention and provide a more detailed description of the present invention. However, the scope of the present invention should not be limited thereto.

In addition, wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts, and a repeated description thereof will be omitted.

In the meantime, although terms including an ordinal number, such as first or second, may be used to describe a variety of constituent elements, the constituent elements are not limited to the terms, and the terms are used only for the purpose of discriminating one constituent element from other constituent elements.

In one embodiment of the present invention, the pixels are processed in raster-scan order from the top left to the bottom right position. The symbol distribution at the current pixel position can be estimated as follows.

Figure 1 shows an illustration of the formation of a current pattern of one embodiment of the method according to the invention. The current pattern of the current pixel x is defined, for

example, by the values of six adjacent pixels a, b, c, d, e, and f with their respective property vectors A, B, C, D, E, and F.

These pixels form a pattern within a defined template. From the top-left position to the current position, the image has to be scanned for identical or similar patterns. This process is also known as template matching, pattern matching, or texture context matching. The main idea is to compare the current pattern at the position of the current pixel having a current value X with patterns in the causal neighborhood.

The higher the similarity between the textures is, the higher the chance is that a value X' is a good estimate for X. This search does not need extra memory and is extremely slow.

Therefore, the search space is typically limited to a maximum distance L from the current position in order to keep the computational costs low.

Unfortunately, patterns outside this search space are usually lost for the estimation of a symbol distribution. The similarity between the patterns could be measured in different ways, for example, based on the absolute differences $|A' - A|$, $|B' - B|$, or the like.

For each pattern found to be similar enough, the value X' at the position of said pattern is collected. The entirety of all X' values has to be processed in a suitable manner forming the symbol distribution. Investigations have shown that patterns with more than six pixels do not improve the results of the invention.

The method and system according to the invention speeds up the search procedure without defining a search space, i.e., without losing any pattern, by storing the contextual patterns, preferably the coordinates of the patterns in the image, in a dynamically generated first list, which is growing during the entire process of image compression.

The first list comprises in the most extreme case all contextual patterns from the past. Together with each contextual pattern, a stacked histogram is stored containing all X values that have occurred so far in the context of the contextual pattern. The frequency counts of these values are successively updated. Based on this technique, the current pattern must only be compared with those patterns which are referenced in the first list.

In addition, a second list is maintained. This second list is empty when starting at a new pixel position and is filled with references to all contextual patterns from the pattern list which are similar to the current pattern surrounding the current pixel. The second list is also referred to as similarity list in the following.

The following pseudo-code relates to an embodiment of the method according to the invention:

```
start with an empty pattern list and empty palette;
reset distributions associated with prediction errors (stage 3):
do
{
  go to the next pixel position;
  // Stage 1
  clear the similarity list; // 'second list'
  set the pointer to the first item in pattern list; // 'first list'
  while (end of pattern list is not reached yet)
  {
   compare current pattern with current item in pattern list;
   if (match found)
   {
     remember best match;
     include found pattern in similarity list;
   }
   set the pointer to the next item in pattern list;
  }
  if (no full match has been found)
  {
   include current pattern in pattern list;
  }
  create distribution based on pattern items in similarity list having best match;
  if (X is element of the distribution)
  {
   encode number of X;
  }
  else
  {
   encode exception handling symbol (stage−1 ESC);
   // Stage 2
   if (X is element of the palette)
   {
    encode number of X;
   }
   else
   {
    encode exception handling symbol (stage−2 ESC);
```

```
39        // Stage 3
40        for each component of X
41        {
42          predict component using MAP prediction;
43          encode prediction error;
44          increment count of error symbol;
45        }
46        append X to palette;
47      }
48       increment count of the stage−2 symbol;
49     }
50     update histograms of all items in similarity list having best match (i.e. increment
       count of the stage−1 symbol);
51   } while (end of image not reached yet);
52   stop;
```

Hereinafter, the above pseudo-code is also referred to as Listing 1. According to an embodiment, e.g., the embodiment of Listing 1, processing a single current pixel may require up to three stages within the probability-modelling step.

In the first stage, the current pattern is compared to the contextual patterns in the first list. All patterns found to fulfill a similarity criterion are collected in the second list. The similarity criterion is explained below. Those contextual patterns having the highest similarity, referred to as having best match are further taken into account. Their associated histograms are merged to a single distribution. If the current property vector X is an element of the merged histogram, the corresponding histogram count of property vector X is encoded, and the histograms of all patterns which have contributed to the merged distribution, are updated. Either the count of X is incremented or X is included as a new histogram item for the corresponding pattern with a count of one.

In a preferred embodiment, all counts are regularly down-scaled enabling the adaptation of the distributions to the varying image content. In the disadvantageous case that the property vector X has never been seen before in combination with the found similar patterns, i.e., X is not an element of the merged distribution, an exception handling is initiated and the processing enters stage 2. This is also the case when no similar patterns had been found.

In a preferred embodiment, each histogram also contains a special symbol, called ESC, for the exception handling, which is encoded in the exception handling.

The underlying assumption of the second stage is that the current property vector X is not a new one, but has already been observed in the past and is an item of the palette. If this assumption holds true, the corresponding palette symbol is encoded and its count is incremented. Otherwise, another exception handling is initiated and the processing enters the third stage. In the exception handling, another ESC symbol must be encoded and stage 3 is entered, which separately processes each component of the property vector X.

The third stage is only used when a new property vector is detected. In one embodiment of the invention, the processing in the third stage relies on local symbol correlation. Preferably based on a median adaptive prediction (MAP), each component of the current property vector X is predicted and in one embodiment the prediction error is encoded based on the error distribution, which is updated afterwards. The skilled person realizes that other representations of the property vector may also be encoded in the third stage. Furthermore, since X is a new property vector, the vector is to be included in the palette with a count of one.

In the embodiments described above, methods of the second and the third stages have a moderate efficiency. For this reason the described method is less suitable for images with a high number of different property vectors.

In a preferred embodiment, the property vector is the color vector in an RGB image. In one embodiment, before the described compression method is applied, the color images in RGB format are converted to another color space, e.g., a kind of YUV. One out of more than 100 different reversible color transforms is adaptively chosen. Afterwards, the histogram of each color component is packed, i.e., the gaps in the histogram are removed leading to a reduced number of histogram bins. In this embodiment, if, e.g., a color component contains only the three different values 5, 10, and 200, these values are mapped to 0, 1, and 2.

A mapping table which contains the three original values is transmitted, enabling a decoder to properly reconstruct these values. If the number of empty bins between the present values is too low, the histogram compaction is disabled. In general, the generated overhead, i.e. table plus table length, is lower than the savings by the improved compression performance.

In all described embodiments of the invention, the definition of similarity is a crucial part in the pattern search and list generation. In a preferred embodiment of the invention, six tolerance thresholds t_i per color component are present with typically t_i being smaller or equal to t_i+1.

If $|A - A'| \leq t_0$, $|B - B'| \leq t_1$, $|C - C'| \leq t_2$, $|D - D'| \leq t_3$, $|E - E'| \leq t_4$, $|F - F'| \leq t_5$ for each component of the property vector, then the two patterns are considered as similar to a full match.

As the characteristics can be different in the three components of the property vector, their threshold can also be different. In one embodiment of the invention, the thresholds are newly determined for each image based on a heuristic entropy measure.

Six joint entropies are calculated separately for each vector component:

$$H(XY_i) = \sum_{k=1}^{K}\sum_{j=1}^{K} p(x_k,y_j) \cdot \log_2\left(\frac{1}{p(x_k,y_j)}\right) \; i = 0,1,\ldots,5$$

with K being the number of different signal values, while X and $Y_i \in \{A, B, C, D, E, F\}$ are the respective property vectors at the corresponding pattern positions shown in Figure 1. The joint probability $p(x_k,y_j)$ is estimated based on the frequency with which the vector X and the vector Y jointly occur. The thresholds are derived via

$$t_i = \lfloor 0.06 \cdot 1.3^{H(XY_i)+e_i} \rfloor \text{ with } e_i = \begin{cases} 0.0 \text{ for } i = 0,1 \\ 0.4 \cdot \sum_{i=0}^{1} H(XY_i) \text{ for } i = 2,3 \\ 0.4 \cdot \sum_{i=0}^{3} H(XY_i) \text{ else} \end{cases}$$

while all factors are empirically determined.

The more uniformly distributed the different combinations of property vectors are, i.e. high joint entropy, the higher the thresholds should be in an embodiment of the invention.

For the images being tested, t_0 and t_1 are equal or close to zero and the maximum observed value is $t_i = 26$. In one embodiment of the invention, the thresholds have to be transmitted to the decoder.

In a preferred embodiment of the invention, the first list is growing during the entire coding process and is filled successively with distinct contextual patterns which have been found in the image. If the tolerance parameters t_0 to t_5 are set to zero for all vector components, the first list will finally contain all different patterns of the image. Otherwise it will only contain a subset of patterns. This can be understood as vector quantization in the pattern space.

In one embodiment of the invention, the current pattern is compared to all contextual patterns in the first list. In the beginning of the compression of an image and depending on the image content, the chance of finding a full match in the first list can be low. In order to improve the compression performance, incomplete matches are also allowed in order to gather some useful information about the putative probability of X. Therefore, those contextual patterns which are similar in less than the six positions A to F will also be regarded as being similar in a preferred embodiment of the invention. If at least A or B fulfills the similarity criterion, it is referred to as a match.

In one embodiment of the invention, the similarity value is simply the count of the positions which are similar.

In a preferred embodiment of the invention, the similarity value is simply the count of the positions which are similar, with two exceptions. Firstly, if the vectors are neither similar at A nor at the B position, then the similarity is set to zero. Secondly, position E is only taken into account when position A is similar; the same holds true for F and B.

For example, an ABCDEF match is a full match with similarity s = 6, an ABEF match has s = 4, CDEF results to $s = 0$, a BCEF match has $s = 3$, and an AE match has $s = 2$. The highest observed value s refers in Listing 1 to 'best match' s_b.

In one embodiment of the invention, if, after the entire first list has been scanned and there was no full match, the actual pattern represents something new and has to be included in the first list. The histograms from all patterns p in the second list which have best match $s_b = \max_{\forall p}(s_p)$ are merged, forming the distribution for the encoding of the current property vector X.

The combination of variable tolerances t_i, the flexible similarity measure, and the merging of contextual information stemming from different contextual patterns is called soft context formation (SCF).

The skilled person will appreciate a number of additional steps to improve the performance of the embodiments of the invention described above without departing from the scope of the present invention. These further improved concepts may be combined in any number or combination with any embodiment of the invention.

In a preferred embodiment, block prediction is used. Screen content often shows regions of constant color or regions of horizontal or vertical stripes. In principle, the proposed processing strategy in the first stage can perfectly deal with these structures. However, the probability distributions will lean towards a single symbol and the interruption of the run of this single symbol can be very costly.

In order to alleviate this scenario, the entire image is analyzed based on quad-tree decomposition. If there are blocks which can be predicted horizontally or vertically, they are identified and corresponding side information is then sent to the decoder. The maximum block size used is preferably 64×64 pixels, the minimum size is preferably 8×8. The quad-tree starts with two levels. The tree depth is adaptively increased, when at least one block show a sufficient high number of different colors.

In one preferred embodiment, prediction of directional structures is used. This embodiment also corresponds to the first stage, while tackling the opposite behavior. At the beginning of a region containing a single symbol, it takes some time until the distribution shows a significant peak representing the high probability of this symbol. If, however, the current pattern is identical to the pattern to the left, then the chance is high that the current X is also identical to its left neighbor. As a consequence, the probability of the left vector should be set to a higher value than derived in the merged histogram. The same can be assumed in vertical direction. In an embodiment of the invention, this assumption is verified at each instance of these arrangements and, if it holds true in more than 50% of these cases, the probability of the symbol to the left or top is increased accordingly.

In one preferred embodiment, a second stage tuning is used. In the second stage, the property vector X is encoded based on a global distribution, i.e., the palette, taking into account all pixels which have already been processed. Local correlations, however, are neglected. Since images with a sufficient number of different property vectors are typically exhibiting some local correlation, the distribution should be modified.

In one embodiment of the invention, the current property vector, separately for each component, is estimated using median adaptive prediction (MAP). The counts of all palette colors which have a Chebychev distance of less than a certain value, preferably 8, to the estimated property vector, are temporarily increased by a distinct amount, preferably by a factor of eight. This reflects the fact that adjacent pixels most likely have a similar property vector.

In one preferred embodiment an improved MAP is used in the third stage. In the third stage, one component after the other has to be predicted and encoded. For the first component, the MAP adaptively selects one out of the three prediction values (estimates) A, B, and (A + B − C).

In one embodiment of the invention, the corresponding prediction error is transmitted and received at the decoder. It is possible to check which estimate would have been the best choice. Assuming that directional structures are similar in all three components, this best predictor is applied to the next component. In order to increase the prediction performance, the set of predictors is extended by C, D, (A + B)/2, and (A + B + C + D + 2)/4. The exact settings used in the described tuning techniques are not reported in detail here as they are empirically determined and have the potential to be improved.

Figures 2 and 3 show block diagrams of one embodiment of the invention. In Figure 2, an embodiment of the first stage is shown and in Figure 3, embodiments of the second and third stage are shown.

Prior to the first stage in an initiation step S100, an empty first list, i.e., a pattern list, and an empty palette is created. Then the in step S201 the next pixel, in case of a new scan the first pixel, is selected and the first stage of processing is entered.

In the first stage in step S202, the second list, i.e., the similarity list is cleared. In a next step S203, the current pattern is compared with the next item on the contextual pattern list. In case a match is found, i.e., step S204 returns positive result, the best match is remembered and the pointer to the pattern under test is included in the similarity list in step S205.

The skilled person realizes that the terms match and best match refer to a result of a similarity comparison as described in the above.

If S204 returns a negative result, the method advances in the contextual pattern list in step S206 and repeats step S203 until the end of the pattern list is reached in S206.

In a next step, S207, the method checks if a full match was found, again referring to the result classification of the similarity comparison.

In case a full match is found in step S209, all histograms of the best match items are merged into a single distribution. If no full match is found, first the current pattern is included into the pattern list in S208, and second all histograms of the best match items are merged into a distribution.

In step S210, it is checked if the property vector X is found in the distribution. If X is found in the distribution a distribution index of X is encoded S211, the method proceeds in step S212 to update the histograms for best match items, and in step S500, either proceeds to the next pixel or stops if the last pixel was processed in S500.

If X is not found in the distribution, an exception symbol ECS1 will be encoded in S212 and the method will proceed to stage 2 in step S300.

Figure 2 shows the details of step S300, i.e., the second and the third stage according to an embodiment of the invention.

In step S301, it is checked whether or not X is found in the palette. In case X is found in the palette in step S302a, the palette symbol of X is encoded, followed by step S303 of updating the palette count of X, by step S304 of updating the histograms for best match items, and by step S500.

In step S301, it is checked whether or not X is found in the palette. In case X is not found in the palette in step S302b, an exception symbol ESC 2 is encoded and the method proceeds to the third stage.

In the third stage in step S401, the vector X is predicted; in a preferred embodiment of the invention, an MAP prediction algorithm is used in step S401.

Then in step S402, the corresponding prediction values of the components of X are encoded, followed by including X in the palette in step S403, updating the prediction error distribution in step S404, by step S405 of updating the histograms for best match items, and by step S500.

In the tables 1a and 1b the compression performance for different specific embodiments of the invention is listed.

Table 1a: File size in bytes for different embodiments of the invention and different images

Image	Number of colours	plain method	block prediction	directional mode
0825.image_153FF4F_880x616	1825	13978	13872	13889
408px-Killersudoku_408x408	396	2377	2395	2335
5colors_544x544	7	3073	3082	3069
6471.clip_image013_496x504	3246	24084	24052	23995
76167_600x496	696	11013	10920	10952
7966_Promax_Social_632x584	6818	53280	53112	53093
800px-FBReader.0.1_800x600	6970	91987	92059	91769
8103.screen05_58DD_600x504	472	9221	9138	9138
8176.CustomControl_608x360	2297	18660	18616	18586
Acid3detailFirefox_680x584	3588	35867	35811	35705
ACTIN_464x392	29	5569	5534	5551
Adminer03_800x384	256	7617	7606	7550
android_report_536x456	1186	11298	11230	11221
Article.Manager_992x448	256	19975	19980	19884
b001793kf7_800x600	247	54081	53951	54035

BALLZ_648x504	1002	13009	13024	12942
BBCNaked_712x520	208	8853	8794	8763
browsedatatabs_1080x648	459	22663	22657	22563
CEANATPE-SecondS_1000x544	112	16057	16079	15931
chart2_976x688	882	5633	5673	5561
chrome-extension_472x264	5782	29947	30285	29889
cinemahist_576x440	255	12490	12440	12395
ciudad-2_0_592x840	1836	83486	83507	83356
clipboard-and-scre_640x544	378	6139	6075	6024
cLznC_736x792	68	2827	2800	2790
Cone-response_544x344	122	6914	6893	6874
ContentPublisherTY_696x536	248	32440	32351	32377
content_1176x400	128	31568	31567	31460
Content_Manager_b_1296x712	5927	39581	39444	39328
convert-pdf-to-bmp_496x344	256	25841	25845	25787
F6_medium_440x256	256	17750	17751	17749
feature-screen-rea_760x712	128	20270	20128	20115
feed_content_bb_616x456	7354	59182	59229	59102
fonctionnalites-09_648x368	256	58486	58372	58401
ga-high-10_456x456	32	17436	17447	17414
global-multi-scree_560x688	7372	54803	54233	54397
graphic-multi_scre_712x440	5863	42293	42166	42196
g_black_hole_392x248	255	4772	4766	4693
I-love-science102_1024x768	199	137400	137214	137363
IC463831_408x152	254	4045	4044	4042
import-screen_1000x648	2109	37427	37375	37278
Landscape_2080x744	645	7416	7350	7436
logo_640x480	2	837	842	832
ls-html-screen-pic_984x696	1519	21985	21821	21828
main_page_392x544	6596	57086	57100	57054
mrstfeatscin_408x232	254	9459	9460	9445
MS_shift_in_rental_912x632	2985	27327	27185	27157
nextguide-usasyn_2048x1536	2963	74411	74169	74107

Raritan1_776x368	600	11098	11059	11026
science_632x568	6680	85168	85077	85116
science_process_di_800x848	256	52220	52186	52106
Science_Wraps_2010_944x784	96	76540	76563	76535
screen-capture_600x448	256	51747	51743	51690
Screen-Searchmetri_968x576	2116	23113	22995	22982
Screen-shot-2013-0_584x576	116	14963	14946	14843
Screen-Shot-2013-_1424x888	4809	40913	40886	40784
Screen-Shot-2015-0_688x456	252	126151	126166	126151
Screen_content_art_352x240	292	3417	3420	3404
stadtplan-museum-o_880x600	64	109982	109990	109675
SUFig-57_472x472	256	13195	13110	13147
topcategorychart_856x480	4793	35194	35058	35128
tux-agafix_1200x1640	602	80345	80099	80288
Windows-Live-Write_376x248	404	4257	4227	4221
WOBIB_140_416x416	9	5270	5252	5266
worddavf15bfb5a46c_592x312	926	9130	9099	9115
XchatScreenshot2__1016x696	1862	26320	26068	26145
Z-scheme_(cs)_808x280	856	12674	12628	12596
total sum		**2133610**	**2130016**	**2127639**

Table 1b: File size in bytes for different embodiments of the invention and different images (Table 1a continued)

Image	Bytes stage 2 tuning	MAP extended	all tunings	SCF adaptive
0825.image_153FF4F_880x616	13835	13880	13579	13579
408px-Killersudoku_408x408	2355	2288	2244	2244
5colors_544x544	3073	3072	3074	3074
6471.clip_image013_496x504	23185	23942	22940	22940
76167_600x496	10986	10942	10769	10769
7966_Promax_Social_632x584	52381	52319	51128	51128
800px-FBReader.0.1_800x600	88994	91482	88414	88414
8103.screen05_58DD_600x504	9211	9209	9050	9050

8176.CustomControl_608x360	18136	18725	18111	18111
Acid3detailFirefox_680x584	33834	35332	33121	33121
ACTIN_464x392	5628	5569	5576	5518
Adminer03_800x384	7639	7617	7567	7545
android_report_536x456	11018	11094	10691	10691
Article.Manager_992x448	19080	19965	18990	18990
b001793kf7_800x600	50056	54077	49891	49891
BALLZ_648x504	12786	12915	12641	12641
BBCNaked_712x520	8933	8849	8792	8712
browsedatatabs_1080x648	22698	22601	22532	22532
CEANATPE-Second-S_1000x544	16497	16052	16391	15951
chart2_976x688	5539	5604	5497	5497
chrome-extension_472x264	29583	29440	29421	29421
cinemahist_576x440	12284	12465	12142	12142
ciudad-2_0_592x840	81273	83374	81052	81052
clipboard-and-scre_640x544	6163	6148	6002	6002
cLznC_736x792	2843	2826	2786	2771
Cone-response_544x344	6998	6908	6941	6857
ContentPublisherTY_696x536	29673	32422	29517	29517
content_1176x400	31530	31566	31425	31425
Content_Manager_b_1296x712	38118	38626	36839	36839
convert-pdf-to-bmp_496x344	24149	25839	24100	24100
F6_medium_440x256	15805	17738	15796	15796
feature-screen-rea_760x712	19475	20270	19216	19216
feed_content_bb_616x456	57414	58766	56977	56977
fonctionnalites-09_648x368	56416	58491	56228	56228
ga-high-10_456x456	17444	17436	17433	17425
global-multi-scree_560x688	53527	52974	50976	50976
graphic-multi_scre_712x440	41003	41115	39661	39661
g_black_hole_392x248	4855	4762	4765	4682
I-love-science102_1024x768	133289	137398	133071	133071
IC463831_408x152	4013	4020	3988	4019
import-screen_1000x648	35367	37301	35067	35067

Landscape_2080x744	7270	7404	7186	7186
logo_640x480	837	837	836	836
ls-html-screen-pic_984x696	21705	21947	21414	21414
main_page_392x544	54045	56766	53709	53709
mrstfeatscin_408x232	9522	9434	9483	9422
MS_shift_in_rental_912x632	26850	27250	26522	26522
nextguide-usasyn_2048x1536	69531	73724	68348	68348
Raritan1_776x368	10584	11080	10473	10473
science_632x568	82282	83947	80938	80938
science_process_di_800x848	48876	52215	48740	48740
Science_Wraps_2010_944x784	77085	76539	77103	76558
screen-capture_600x448	50051	51738	49984	49984
Screen-Searchmetri_968x576	22823	22866	22375	22375
Screen-shot-2013-0_584x576	15526	14956	15393	14829
Screen-Shot-2013-_1424x888	39629	40377	38979	38979
Screen-Shot-2015-0_688x456	120479	126127	120469	120469
Screen_content_art_352x240	3420	3405	3399	3399
stadtplan-museum-o_880x600	110493	109983	110198	109685
SUFig-57_472x472	12585	13195	12463	12463
topcategorychart_856x480	33982	34601	33230	33230
tux-agafix_1200x1640	78818	80313	78475	78475
Windows-Live-Write_376x248	4260	4233	4182	4182
WOBIB_140_416x416	5270	5270	5248	5248
worddavf15bfb5a46c_592x312	8802	9051	8683	8683
XchatScreenshot2__1016x696	26289	25927	25542	25542
Z-scheme_(cs)_808x280	12248	12623	12093	12093
total sum	**2070348**	**2121227**	**2049866**	**2047427**

The compression scheme has been tested using 67 images. These images mainly have synthetic content like diagrams, charts, text, and snapshots from screens.

The column 'plain method' shows the file sizes when all tuning methods are disabled. The total number of bytes is 2 133 610. The next four columns to the right contain the results for

cases where one of the four tunings discussed above is enabled. The decreased total sums show that all four modifications have a positive effect on average, while the stage-2 tuning obtains the most significant improvement. The 'block prediction' has the smallest effect on the compression performance and even increases the file size by some bytes for some images.

The latter is caused by the overhead for transmitting the quad-tree structure. The maximum savings are reached for 'global-multi-screen 560x688' with 570 bytes. The main advantage of 'block prediction' is not only the bit savings but the reduced processing time, when large areas can be predicted and do not have to be processed pixel by pixel.

The 'directional mode' also saves only few bytes per image, since there are, in general, only few positions in the image where this mode can take action.

Although 'stage-2 tuning' seems to benefit the compression performance most, there are some images with a performance drop compared to the plain scheme (Screen-shot- 2013-0 584x576 a.o.). This typically concerns images with only a few colors. Here, the local correlations are low in general, or the MAP prediction is not appropriate for estimating the current color – for example, when color gradients (shadings) are generated using dithering techniques (e.g. Science Wraps 2010 944x784). In the final program version, 'stage-2 tuning' is adaptively disabled in these cases. The modification of the MAP estimation of color components (column 'MAP extended') has a positive effect on nearly all images in the test. The image 'global-multi-screen 560x688' benefits most with savings of 1 829 bytes.

The fewer colors an image has, the less frequently the processing in the third stage is required, and the influence of this tuning technique decreases. The column 'all tunings' shows that the positive effects of all four modifications accumulate. The column 'SCF auto' contains the file sizes when 'stage-2 tuning' is automatically disabled.

As the pattern list and the similarity list, i.e., the first and the second list, are automatically generated in the course of compression, the memory consumption might be of interest. Especially the pattern list can grow until the last pixel has been coded. The size of the list depends on the number of different patterns in the image which is, in the worst case, equal to the number of pixels, when all tolerance thresholds are set to zero.

It is important to mention that the pattern list must not store the contextual patterns themselves, since these patterns are already in the image array. The list solely maintains the corresponding addresses, i.e., one pointer per contextual pattern. In addition, a pointer to the next list element is required (chained list). The histograms associated with each single pattern are the second factor in memory-space estimation.

Theoretically, the number of RGB triplets to be stored per pattern is equal to the number of different colors in the image. Each triplet has to be supplemented with its frequency. It is relevant for the skilled person what the maximum number of triplets is that must be stored in practice. This can be derived as follows: It is assumed that the number of pixels in the image is equal to N. Then, the maximum number of different color triplets is equal to N as well as the number of different patterns.

In this case, each pattern occurs in combination with a single triplet, that means, only N triplets must be stored. If one pattern P_0 appears twice, the number of different patterns is reduced to $N-1$. The pattern P_0 can have combinations with two different color triplets, while all others still have a single color assigned. If the number of different patterns is reduced to $N-2$, either one pattern can appear in combination with a maximum of three different colors, or two patterns appear in combination with two colors, and so forth.

In total, the number of triplet entries can never exceed N and the similarity list merely contains pointers to those entries of the pattern list that are found to be similar to the current pattern. Depending on the tolerance thresholds, only few pointers have to be stored.

A Comparison between different state of the art methods, namely LOCO, 7zip, HEVC (including SCC extension), FP8v3, and the present invention has been performed. The test images used in this comparison have less than 8 000 colors. LOCO, including the adaptive color-space conversion that is also used for the present invention, achieves the worst results as it is not designed for synthetic images. The performance may be improved by using a color palette instead of RGB/YUV triples.

The archiver program 7zip (Ultra, LZMA) shows a distinctly better compression, even though it does not exploit the two-dimensional characteristic of the data. The new video compression standard HEVC has been applied using the standard configuration of the screencontent-

coding extension (SCM-6.0, encoder intra main – scc lossless.cfg, InputColourSpaceConvert= RGBtoGBR). The tools for screen content (cross component prediction, intrablock copy, ACT, and palette mode,) had been enabled. HEVC produces much smaller files than LOCO or 7zip on average.

FP8 version 3 is an archiver program based on context mixing that is dedicated to images. It was executed with option '-8' and outperforms HEVC. On average, however, the present invention compression leads to best results. The savings are more than 20% compared to HEVC and about 4% compared to FP8.

The present invention outperforms HEVC for images containing up to 30 000 colors, while the performance is comparable when considering other images. The evaluation of HEVC and the present invention has been supplemented with investigations about the order of color components.

The present invention estimates a proper distribution of contextual probabilities for each single pixel position. It is based on a technique that stores a subset of all occurring contexts (patterns) in a linked list. Compared to simple template matching, the proposed invention can take information from all processed pixels into account without being too time consuming. The soft definition of a pattern match, i.e., application of tolerance thresholds, incomplete matches, and the aggregation of knowledge from different patterns, in combination with a three-stage probability modeling are used in the present invention.

With an increasing number of colors, coding stage 1 becomes less effective and the process has to enter stage 2 or stage 3, which both still have potential for improvement. In principle the used prediction technique is limiting the performance. Nevertheless, in application to screen-content images used in the standardization of HEVC, the present invention still performs better than HEVC for images with up to about 30 000 colors. In general, block segmentation as in HEVC and switching between different processing strategies would benefit the processing. Regions with a low number of colors could be compressed using the present invention, while other regions could predicatively be processed.

The skilled person realizes that the above described method and system result in a lossless compression. However, the same system and method can be also used for near-lossless or even lossy compression.

Preferably the method would encode in the first stage even if no exact match for X is found in the distribution, but a match for X is found within a certain acceptable range in the distribution.

Preferably the method would encode in the second stage even if no exact match for X is found in the palette, but a match for X is found within a certain acceptable range in the palette.

Encoding X in an earlier stage will reduce the computational effort. However, depending on the acceptable range the earlier encoding will result in near-lossless or lossy compression. Preferably, the decision about the acceptable range is made based on rate-distortion optimization, while the measure of distortion can be either dependent on an objective measure or based on the human visual system (subjective measure).

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and non-restrictive; the invention is thus not limited to the disclosed embodiments. Variations to the disclosed embodiments can be understood and effected by those skilled in the art and practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality and may mean "at least one".

CLAIMS

1. Method for encoding an image, in particular for reducing the computational complexity for encoding the image, based on an optimal estimation of a distribution probability, wherein the method comprises encoding of at least one symbol for a property vector X of a respective current pixel of a plurality of pixels in sequence based on contextual patterns formed by respective property vectors of a plurality of neighboring pixels of the current pixel, wherein the encoding of at least one symbol for a property vector X comprises

a) encoding a distribution symbol of the property vector X from a distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel,

when the property vector X of the respective pixel occurred in the distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel;

b) encoding a first stage exception handling symbol and a palette symbol of the respective property vector X of a dynamically generated palette of property vectors,

when the respective property vector X of the respective pixel has not occurred in the distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel; and

c) encoding a first stage exception handling symbol, a second stage exception handling symbol, and a representation of all components of the property vector X, when the property vector X has not occurred in the distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel and the property vector X is not found in the palette.

2. The method of claim 1, wherein the similarity between two contextual patterns is determined based on the comparison of at least one threshold value with a modulus of a vector difference of the property vector of at least one pixel of the respective contextual pattern and a pixel in a corresponding position of the pattern referred to in the first list.

3. The method of claim 1 or 2, wherein a similarity value is calculated from the individual distance measures between property vectors in the corresponding positions in the respective patterns, and/or

wherein a similarity value is the count of positions in the contextual pattern which are similar to the corresponding positions in the other pattern.

4. The method any one of claims 1 to 3, wherein during the encoding of the image a first list is dynamically generated, which comprises references to patterns found in the image and further comprises for every respective pattern a histogram containing a distribution of all property vectors X which have occurred in the respective pattern during the scan, and wherein when during the encoding of the respective pixel no corresponding pattern is found in the first list, the respective pattern is appended to the first list, wherein the patterns comprised in the first list are not identical.

5. The method of any one of claims 1 to 4, further comprising the steps of

updating the property vector distribution of the palette after the encoding of the first stage exception handling symbol and the palette symbol of the respective property vector X; and

updating a prediction error distribution after the encoding of the first stage exception handling symbol, the second stage exception handling symbol, and the prediction error.

6. The method of any one of claims 1 to 5, wherein during the encoding of a respective property vector X a second list is dynamically and temporally generated, based on a calculated similarity value,

wherein the second list comprises a reference to at least one contextual pattern of the first list being similar to the contextual pattern of the neighboring pixels of the respective pixel or

wherein the second list is empty when no similar pattern has been found to the contextual pattern of the neighboring pixels of the respective pixel.

7. The method of any one of claims 1 to 6, further comprising the step of updating the respective histograms of patterns referred to in the first list after the encoding of the respective property vector X.

8. The method of claims 6 or 7, wherein the distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective

pixel, is generated by merging the respective histograms of all items on the second list having a highest similarity value.

9. The method of any one of claims 2 to 8, wherein a set of thresholds for each of the positions in the contextual pattern is determined based on image properties.

10. The method of any one of claims 2 to 9, wherein the thresholds are variably adapted during the encoding.

11. The method of any one of claims 1 to 10, further comprising the step of reducing the number of items on the first and/or second list by
a) deleting at least one pattern which is determined as not being relevant not been recently found to be similar from the first list, and/or
b) deleting at least one pattern which is determined as not being relevant with a similarity value smaller than the highest similarity value from the second list.

12. The method of any one of claims 1 to 11, wherein the representation of all components of the property vector X is based on a prediction of the components and wherein for a first component a preferred prediction method is determined and the preferred prediction method is used to predict all further components.

13. Computer program product comprising one or more computer readable media having computer executable instructions for performing the steps of the method of one of the preceding claims.

14. System for encoding an image, in particular for reducing the computational complexity for encoding the image, based on an optimal estimation of a distribution probability, the system is configured to encode at least one symbol for a property vector X of a respective pixel of a plurality of pixels in sequence based on contextual patterns formed by respective property vectors of a plurality of neighboring pixels of the respective current pixel, the system comprising:

an encoding unit being configured to encode a distribution symbol of the property vector X from a distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel, when the property

vector X of the respective pixel has occurred in the distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel,

wherein the encoding unit is configured to encode a first stage exception handling symbol and a palette symbol of the respective property vector X of a dynamically generated palette of property vectors, when the respective property vector X of the respective pixel has not occurred in the distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel, and

wherein the encoding unit is further configured to encode a first stage exception handling symbol, a second stage exception handling symbol, and a representation of all components of the property vector X, when the property vector X has not occurred in the distribution of the property vectors found in the contextual patterns that are identical or similar to the contextual pattern of the respective pixel and the property vector X is not found in the palette.

15. System according to claim 14, comprising means being configured to determine the similarity between two contextual patterns based on the comparison of at least one threshold value with a modulus of a vector difference of the property vector of at least one pixel of the respective contextual pattern and a pixel in a corresponding position of the pattern referred to in the first list.

DRAWINGS

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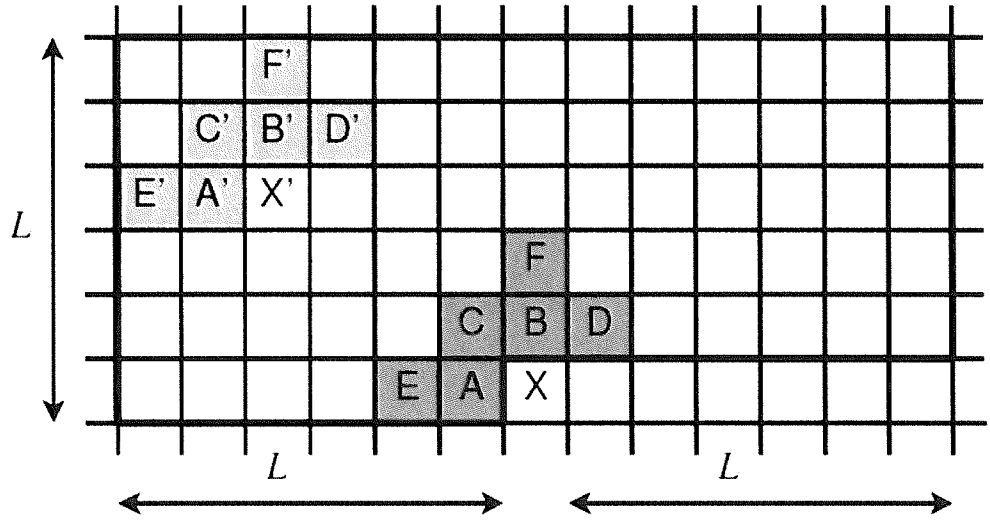


Fig. 1

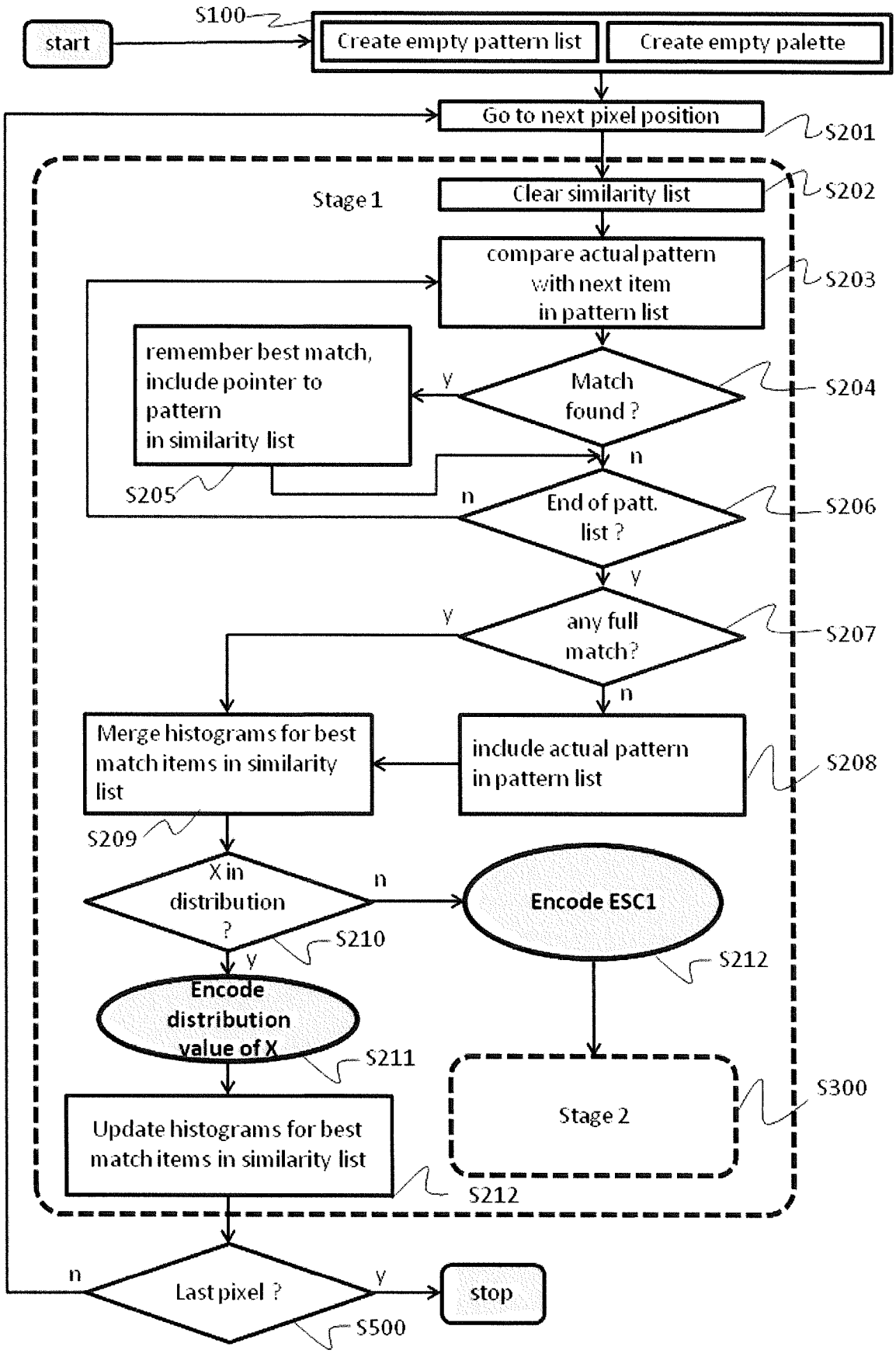

start
S100
Create empty pattern list
Create empty palette
Go to next pixel position
S201
Stage 1
Clear similarity list
S202
compare actual pattern with next item in pattern list
S203
remember best match, include pointer to pattern in similarity list
y
Match found ?
S204
n
S205
n
End of patt. list ?
S206
y
y
any full match?
S207
n
Merge histograms for best match items in similarity list
include actual pattern in pattern list
S208
S209
X in distribution ?
n
Encode ESC1
S210
S212
y
Encode distribution value of X
S211
Stage 2
S300
Update histograms for best match items in similarity list
S212
n
Last pixel ?
y
stop
S500

Fig. 2

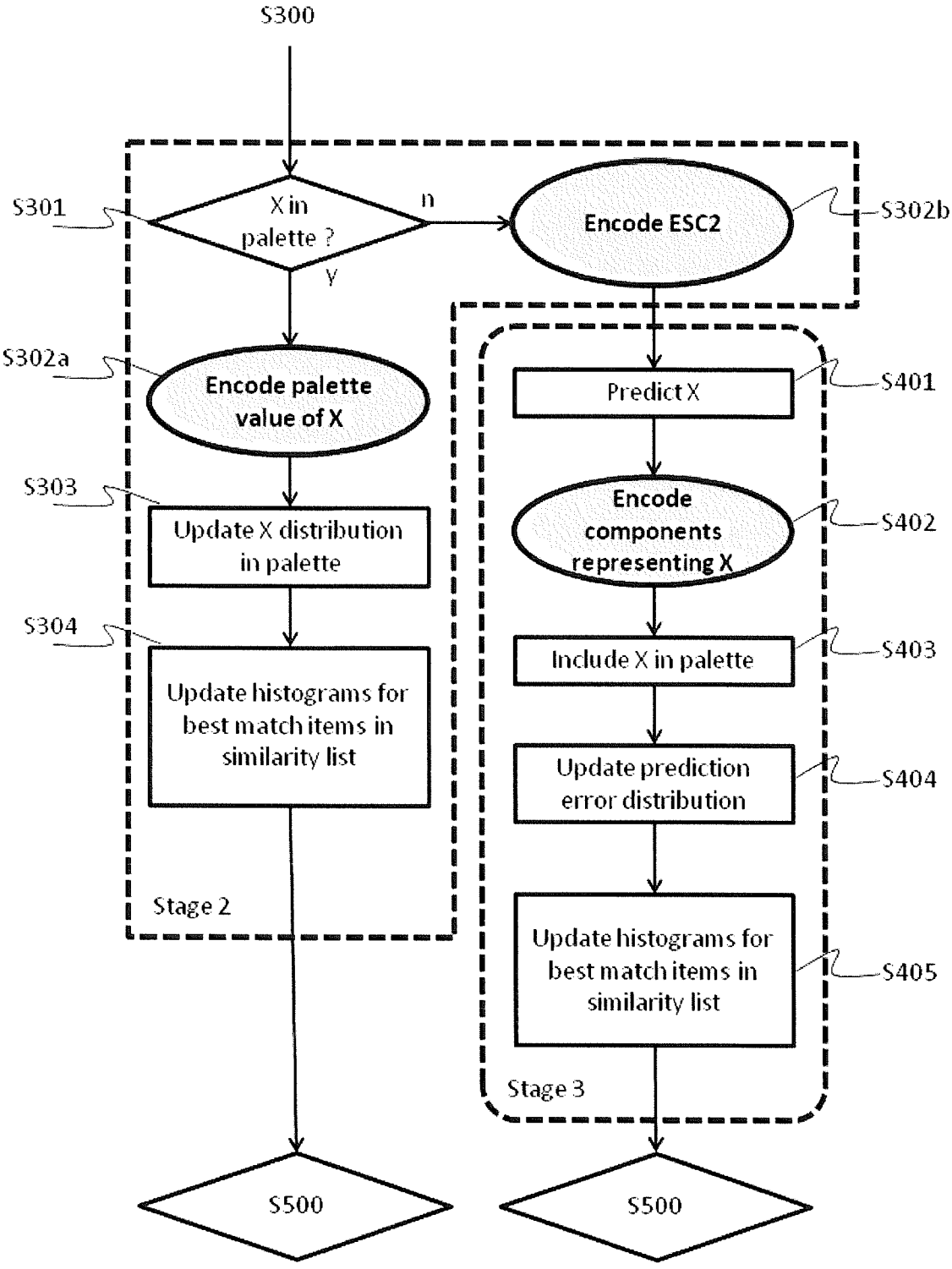

S300
S301
X in palette ?
n
y
Encode ESC2
S302b
S302a
Encode palette value of X
S303
Update X distribution in palette
S304
Update histograms for best match items in similarity list
Stage 2
S401
Predict X
S402
Encode components representing X
S403
Include X in palette
S404
Update prediction error distribution
S405
Update histograms for best match items in similarity list
Stage 3
S500
S500

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/078074

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04N19/13 H04N19/593 H04N19/94
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, COMPENDEX, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	STRUTZ TILO: "Lossless Intra Compression of Screen Content based on Soft Context Formation", IEEE JOURNAL ON EMERGING AND SELECTED TOPICS IN CIRCUITS AND SYSTEMS, IEEE, PISCATAWAY, NJ, USA, vol. 6, no. 4, 1 December 2016 (2016-12-01), pages 508-516, XP011636929, ISSN: 2156-3357, DOI: 10.1109/JETCAS.2016.2606550 [retrieved on 2016-12-12] figure 1 section III. "Method" section III.B "Proposed Scheme" ----- -/--	1-15

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 January 2018	17/01/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Stoufs, Maryse

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	HOWARD P G: "TEXT IMAGE COMPRESSION USING SOFT PATTERN MATCHING", COMPUTER JOURNAL, OXFORD UNIVERSITY PRESS, SURREY, GB, vol. 40, no. 2/03, 1 January 1997 (1997-01-01), pages 146-156, XP000738263, ISSN: 0010-4620, DOI: 10.1093/COMJNL/40.2_AND_3.146 section 4 "Compression based on soft pattern matching"	1-15
Y	US 2016/316214 A1 (GISQUET CHRISTOPHE [FR] ET AL) 27 October 2016 (2016-10-27) figures 12, 15, 17 paragraph [0332] - paragraph [0334]	1-15
A	ZHU W ET AL: "Non-RCE3:Template-based palette prediction", 14. JCT-VC MEETING; 25-7-2013 - 2-8-2013; VIENNA; (JOINT COLLABORATIVE TEAM ON VIDEO CODING OF ISO/IEC JTC1/SC29/WG11 AND ITU-T SG.16); URL: HTTP://WFTP3.ITU.INT/AV-ARCH/JCTVC-SITE/,, no. JCTVC-N0169-v3, 30 July 2013 (2013-07-30), XP030114648, figure 1 section 2.1 "Palette template" section 2.2 "Template-based palette prediction and coding"	1-15
A	XU JIZHENG ET AL: "Overview of the Emerging HEVC Screen Content Coding Extension", IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 26, no. 1, 1 January 2016 (2016-01-01), pages 50-62, XP011592177, ISSN: 1051-8215, DOI: 10.1109/TCSVT.2015.2478706 [retrieved on 2016-01-05] the whole document	1-15
A	D. MARPE ET AL: "Context-based adaptive binary arithmetic coding in the H.264/AVC video compression standard", IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, vol. 13, no. 7, 1 July 2003 (2003-07-01), pages 620-636, XP055119784, ISSN: 1051-8215, DOI: 10.1109/TCSVT.2003.815173 the whole document	1-15

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/078074

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 2015091879 A2	25-06-2015