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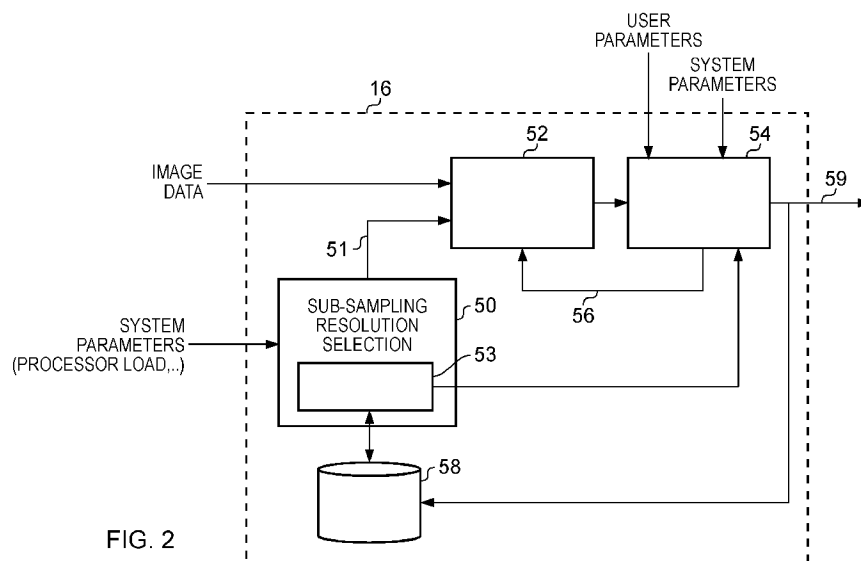


FIG. 2

(57) Abstract: An image processing system analyses image data. Image data is sub-sampled (52) at a selected resolution to construct a histogram. The sub-sampling resolution is selected (50) based on at least one of: results (58) of sub-sampling operations on previous frames of the image data; available resources of the image processing system. A comparison is made between an expected control value and an actual control value obtained from sub-sampling at the selected resolution, and the sub-sampling resolution is changed based on the comparison. The method can be applied to dynamic control of the backlight (24) of a display panel (22). A power budget can be set for the image analysis based on an amount of power which is expected to be saved by reducing the intensity of the backlight (24).



DESCRIPTION

FREQUENCY CONTROLLED CAPACITIVE POWER CONVERTER

5 This invention relates to sub-sampling of image data.

 There are various applications where it is useful to analyse image data to determine characteristics of the image, such as brightness, contrast and colour. Analysing an array of data which represents all of the pixels of the image can
10 require substantial processing resources, and can take an unacceptably long time, especially for a high resolution image. It is possible to analyse a sub-set of the image data, such as one pixel in every N pixels of the image data. This process is known as sub-sampling. By using a sub-set of the image data, a result can be obtained which is representative of the total set of image data,
15 without the need to spend processing resources obtaining a result based on the full set of data.

 US 2005/0053281 describes sub-sampling of image data in an image scanning application. Image data is sub-sampled to acquire a histogram of data of the image, such as brightness levels. The histogram is used to determine
20 settings during the subsequent processing of the image.

 The present invention seeks to provide an alternative method, and apparatus, for analysing image data.

25 Accordingly, a first aspect of the present invention provides a method according to claim 1.

 An advantage of adaptively selecting a sub-sampling resolution is that it is possible to save system resources, such as processing cycles and power, when
30 a high sub-sampling resolution is not required. Also, it is possible to set the sub-sampling resolution at a value which is matched to the system resources. This

can be especially useful where the analysis needs to be performed in real-time and the currently available resources are insufficient to perform a high resolution sub-sampling operation. The sub-sampling can operate on a characteristic such as brightness (luminance) of an element of the image data, and the analysis can
5 be used to determine maximum brightness of a frame of the image data.

The method can select a sub-sampling resolution based on system resources. The image analysis function can be allocated a system resources budget, which is a portion of the resources of the host system. The system resources budget can be a fixed or variable portion of the total resources, or can
10 be set based on the currently available resources. The selection of sub-sampling resolution can be based on the resources allocated to the image analysis function, so that the image analysis uses a resolution which is always within the allocated portion of the system resources. An alternative to setting a particular resources budget for the image analysis function is to select the sub-sampling
15 resolution based on available (free) resources at that particular time, when all of the competing demands on the system are taken into account. So, for example, during periods when there are heavy demands on the resources of the host system, the sub-sampling resolution is lowered, or image analysis is skipped for a particular frame.

It is desirable that the method of sub-sampling should remain accurate and reliable. This means that the calculated results should sufficiently approximate the value which would be found if all of the pixels in a frame of image data were analysed. Advantageously, the sub-sampling resolution is dynamically adapted by evaluating an intermediate result of the sub-sampling
20 operation against a calculated expected result. This evaluation can be performed part-way through sub-sampling a frame of image data. If there is an unacceptable difference between the intermediate result and the expected result then the sub-sampling resolution can be increased, such as by sampling the image data at other spatial positions.
25

The sub-sampling resolution defines the spatial pattern of pixels within a frame of image data which are sampled. The sub-sampling resolution can be
30

varied in the temporal domain, so that different frames of image data are sampled with a different spatial sub-sampling resolution. It can also be advantageous to vary the sub-sampling pattern between frames, even where the spatial sub-sampling resolution remains constant, to avoid a fixed relationship
5 between the sampling pattern and the image contents. A simple way of achieving this is to use the same sub-sampling pattern, with an offset between consecutive frames.

One advantageous application of this method is dynamic backlight control, in which the backlight of a display panel is adaptively varied according to
10 brightness of the image data which is to be displayed. A frame of image data is analysed to determine brightness (luminance) values of the image data. Advantageously, the amount of power used to analyse the image data is less than the amount of power which will be saved by reducing the intensity of the backlight, resulting in a net power saving. This can be achieved by setting a
15 power budget for the image analysis, based on the expected power saving. The power budget can be set at a fraction of the expected power saving, with the fraction determining how aggressively power is saved. The fraction can be set in response to a user input. This also helps to ensure that in situations where there is only a small potential power saving from reducing the backlight intensity, the
20 amount of power expended on image analysis is reduced to a minimum.

The method can also be applied to other applications or control systems where image data is analysed, especially where there is a need to save power, such as an automatic gain control which is part of an image processing system.

25 A further aspect of the invention comprises an image processing system comprising: an image processing device; and a processing apparatus which is arranged to perform the method. The image processing device can comprise a display device (e.g. LCD panel), an image acquisition device (e.g. image scanner, digital camera) or any other form of image processing device.

30 Further aspects of the invention provides apparatus for performing the method and software for performing the method. The software can be provided

as computer-executable code which is tangibly embodied on an electronic memory device, hard disk, optical disk or any other machine-readable storage medium or it can be downloaded to a processing device via a network connection.

5

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

Figure 1 shows a dynamic backlight control system;

10 Figure 2 shows a sub-sampling resolution selection unit for use in the system of Figure 1;

Figure 3 shows a method of adapting the sub-sampling resolution;

Figures 4 and 5 show logic for selecting the sub-sampling resolution;

Figures 6 and 7 show sampling grids which can be used to sub-sample image data.

15

One advantageous application where the invention can be applied is in dynamically controlling the backlight level of a display, such as a Liquid Crystal Display (LCD) panel. Dynamic backlight control is described in WO 2005/109391A1 and will now be summarised. LCD panels include a
20 backlight which illuminates liquid crystal light valves within the panel. The power consumption of the backlight is a significant portion of the total power consumption of the LCD panel. Conventionally, LCD panels are illuminated continuously at a fixed brightness, which is sufficient to render the highest brightness level in a displayed image. The panel is illuminated at this fixed level
25 even when the maximum brightness in the displayed image is well below the maximum value that the backlight is providing illumination for. Dynamic backlight control varies the backlight illumination based on the brightness levels in an image which is to be displayed. Image data is scaled by a gain factor to ensure that the displayed image appears the same as if the backlight were operating at
30 full power. This can considerably reduce power consumption of the LCD panel.

Dynamic backlight control requires that each image to be displayed is first analysed to determine the maximum brightness level and the number of pixels that have this maximum level. This is achieved by a histogram analysis of the image. This means that the brightness level of individual pixels (or sub-pixels) is evaluated and quantified by means of a histogram of these brightness levels. This analysis function can be performed by a processor or by dedicated hardware.

A full analysis of an image, which evaluates the brightness levels of all pixels, takes a substantial number of processing cycles and data bandwidth to the system memory. For high resolution images and/or low power systems, this may inhibit the practical implementation of the dynamic backlight feature. Also, the fixed amount of processing cycles and data bandwidth that arises from analysing a fixed number of pixels, may lead to an unacceptable increase of total system power in cases where no reduction of backlight power is reached (due to bright image contents). A reduction of these values can be obtained by application of a sub-sampling scheme in which only a representative part of the pixels is used for the analysis. Pixels can be skipped in spatial domain (horizontal and vertical direction) and/or in temporal domain (skipping frames in a sequence of images).

Figure 1 shows a dynamic backlight control system for a backlit LCD panel 22. Image data 10 representing an image for display is stored in a memory 12. The image data is analysed by a functional unit 16 which performs a sub-sampling operation on the image data in memory 12. Luminance values of a sub-set of the total set of pixels of the frame of image data are inspected. Unit 16 generates a histogram of luminance values against the number of pixels having each luminance value. The histogram may simplify the analysis by binning ranges of luminance values. So, for example, each bin can correspond to a 5% sub-range in the total range of possible luminance values. Pixels having a luminance level between 95% and 100% are counted in the highest bin, sub-pixels having a luminance between 90% and 95% are counted in the second highest bin, and so on.

Unit 16 calculates a power reduction (attenuation) factor 19 for the display backlight 24, which is output to the backlight 24 of the display. Unit 16 also calculates a scaling factor 17 to be applied to the image data, based on the scaling factor. Unit 16 can inspect the histogram and determine if any of the
5 higher luminance values, or bins, contain no pixels, or only a small number of pixels. If one of these conditions is met, there is an opportunity to reduce the intensity of the backlight and image data can be scaled according to the reduction in backlight intensity. This has the advantage that power consumption of the backlit LCD device can be reduced while substantially maintaining the
10 same image quality.

Unit 18 scales the image data by the calculated scaling factor 17. Unit 20 receives the updated image data values and clips any updated image data values which lie outside of the range which can be displayed.

Figure 2 schematically shows, in more detail, the functional units within the
15 histogram calculation unit 16 of Figure 1. In accordance with embodiments of the invention the image data 10 is sub-sampled, and the sub-sampling resolution is varied based on various parameters. A sub-sampling resolution selection unit 50 receives one or more system parameters, such as processor load, memory bandwidth usage, remaining power (e.g. of a battery-powered device). The term
20 "memory bandwidth" refers to the pipelines which access the memory, for which there will be competition between various elements of the host device. A history analysis unit 53 of unit 50 can access a store 58 of historic data which indicates the recent control values calculated by the unit 16. Unit 53 analyses the historic data to determine trends in the data, and this allows unit 50 to make a decision
25 on selecting the sub-sampling resolution. For example, if the historic data indicates that the control values have not changed over a large number of previous frames, it is likely that the current frame will also not change. Similarly, if the image has recently been bright, there is little opportunity to reduce power of the backlight. Therefore, the sub-sampling resolution can remain at the current
30 value or, more preferably, can be changed to a lower resolution to conserve

power. Unit 50 selects a resolution for the sub-sampling operation and this is output 51 to the histogram calculation unit 52.

Histogram calculation unit 52 receives image data from memory 12 and the selection of sub-sampling resolution 51. Unit 52 constructs a histogram of
5 some characteristic of the image data, such as luminance values.

A histogram evaluation unit 54 analyses the histogram to determine a property of the histogram. For example, the histogram evaluation unit can determine a number of pixels which exceed a particular luminance value. Using the user input for desired picture quality, a maximum fraction of pixels that is
10 allowed to be clipped is determined as follows: the contents of each histogram bin also represents a fraction of the total of pixels. The contents of the histogram bins are summed from the top (high brightness) down until the summed fraction equals or surpasses the maximum fraction allowed to clip. The number of the last bin added indirectly represents the brightness level of the backlight. Some
15 translations may also be required.

Unit 54 also receives user parameters. One such user parameter can define if the power-saving feature is turned on or off. If the feature is turned off, no analysis of the image data may be required. Another user parameter can define an image quality setting. If the dynamic backlight controller sets the
20 backlight beneath the luminance value of the brightest pixels in the image data, then detail in the brightest parts of the displayed image is lost, or clipped. The quality setting can define an acceptable level of clipping to a user, which can equate to a number of clipped pixels. If a user has requested a dynamic contrast setting, then it may be necessary to sub-sample the image data for the purpose
25 of dimming the backlight to improve contrast. Dynamic contrast looks at the number of pixels with (very) low brightness. This information can be extracted from the same histogram.

Advantageously, the histogram is evaluated after a first batch of data has been added to it, such as data obtained by sub-sampling using a first sampling
30 grid. This allows an intermediate result to be determined. The histogram evaluation unit 54 can instruct the histogram calculation unit 52 to perform further

sub-sampling of the image data, such as by using a further sampling grid. An end result 59 is output by the histogram evaluation unit. The end result is also stored as part of the store of historic data 58. There are various options for the data that is stored as historic data. In the example described above, the number of the bin that was last added in the histogram evaluation stage is stored, and the historic data is a list of bin numbers representing the maximum brightness level in a frame of image data. Other options are the attenuation factor for the backlight or the calculated backlight level.

Figure 3 shows steps of a method for analysing image data which can be performed by the functional units of Figure 2. The method begins at step 100 with a new frame of image data which needs to be analysed. Before analysing the new frame of image data, unit 50 analyses historic data. A decision on which sub-sampling resolution to use is based on the historic data and/or system parameters. Some possible ways of making use of the historic data and system parameters will now be described.

If the analysis results of previous frames show that no large power reduction is expected for the next frame, the sub-sampling scheme is changed to a lower resolution. A bright image (i.e. an image having pixels with a luminance value which is near to the maximum possible luminance value) requires the backlight to operate at full power, or close to full power. If a number of previous images have been bright, it is likely that the next image will also be bright. The backlight will need to operate at full intensity, or close to full intensity, and it will not be possible to save much power from backlight reduction. Therefore, it is not useful to expend resources in performing an accurate analysis of the image. A dimmer image (i.e. an image where the brightest pixels have luminance values which are less than the maximum possible luminance value) will allow the backlight to operate at reduced power. There is a good chance that the backlight can be operated at reduced intensity and it will be possible to save some power. Therefore, it is more useful to expend resources in performing a more accurate analysis of the image.

If the analysis results of previous frames indicate little, or no, dynamic behaviour in the luminance values, the sub-sampling scheme is changed to a lower resolution as the likelihood is that the next frame will be similar to the previous ones.

5 If the system status indicates that the processor occupancy is high due to other tasks running on the system, the sub-sampling scheme is changed to a lower resolution. This avoids burdening the processor with the additional processing effort required to sample the image data, which will also help to reduce the computation time.

10 A resolution for the sub-sampling is selected based on one, or a combination, of the system status parameters and/or analysis of the history. In the case of a dynamic backlight control system, the purpose of such a control system is to save power by operating the backlight at lower intensity. However, an amount of power is required by the processor to analyse the image data to
15 decide if the backlight can be reduced. In order to ensure that there is an overall saving of power, a power budget can be set for the amount of power required to analyse the image data, and this power budget can be based on the potential power saving resulting from operating the backlight at reduced power. For example, the power budget could be set a figure of 10% of the potential power
20 saving, e.g. if a saving of 100mW can be saved by reducing the backlight intensity, the analysis is allocated a power budget of 10mW, giving a total saving of 90mW. In some cases it can be more efficient to temporarily turn off the dynamic backlight feature, restoring the backlight to full power and not performing any analysis of luminance values. This can apply, for example, if the power
25 budget is too low to perform the required analysis of the image data, or if the historic data indicates a dynamic image (i.e. higher sub-sampling resolution required) but the system status indicates that the processor is too busy to perform analysis in real-time.

30 As will be described later, the sub-sampling resolution can take the form of a grid of sampling positions. If only a sub-set of all the pixels in an image is used

for the analysis, the result can still sufficiently represent the properties of the total image.

At step 102 the histogram is cleared and the sub-sampling operation begins. A histogram of a characteristic of the image data (e.g. luminance values) is constructed. As described above, the histogram can record a number of pixels meeting a particular value, or sub-range of values, from a range of values of the characteristic. The sub-sampling of a frame of image data can initially be set at a very low sampling resolution, i.e. a very small sub-set of the total pixel population is added to the histogram at the start.

At step 104 an intermediate result is extracted from the histogram data. The intermediate result can give an estimate (by suitable scaling, if necessary) of the final value that will be achieved after the complete sub-sampling operation. The expected result is based on the historic data. The expected result can be a range, determined by the average value of the historic data list and a certain maximum allowed difference value. Advantageously, the expected result is calculated as part of the calculations at step 100 when the historic data is analysed. As an example, consider an intermediate result is acquired using a sampling grid which inspects one in every N pixels, with the result that 10 pixels exceed a threshold of X. By extrapolation, the final result is likely to be N x 10 pixels. The intermediate result may only provide a rough estimate of the final result. The intermediate result is compared against an expected final result. As described above, the expected result can be scaled upwards to form an appropriate comparison with the final result, or the final result can be scaled downwards to form an appropriate comparison with the intermediate result. Some tolerance can be allowed when making the comparison.

At step 106, if the comparison of the intermediate result and the expected final result falls outside of the acceptance criterion, then the resolution can be increased at step 108. This may occur when there is a scene change in video content. The resolution can be increased by adding a further sub-sampling grid. The process of constructing the histogram continues. However, if the comparison of the intermediate result and the expected final result falls within the

acceptance criterion, then the sub-sampling operation is complete and the process continues to step 110. The sub-sampling resolution can be incrementally increased via the loop of steps 104, 106, 108. The sub-sampling resolution can be incrementally increased until a resolution which offers an acceptably accurate value is found. Alternatively, the sub-sampling resolution can be incrementally increased until system resources have been expended, such as available processing resources (e.g. CPU cycles), memory bandwidth or power budget. To limit the number of pixels analysed for one frame, a maximum number of iterations, or a maximum number of sub-sampled pixels can be defined. In situations where there has been a significant change in the image brightness level, it may be necessary to perform analysis at full resolution (i.e. the full set of image data is analysed).

At step 110 the final result is calculated and output. The final result is also added to the historic data.

When the analysis results from previous frames show that little change is to be expected for the next frame (e.g. a series of still images), the starting resolution for that next frame can be reduced (lower spatial resolution) or the decision can even be taken to skip the next frame (lower temporal resolution). Preferably, the expectation value for the next histogram analysis is adjusted to allow for a larger difference with previous results as these are based on a different sub-set of the pixel population.

Figures 4 and 5 show decision logic for selecting the sub-sampling resolution based on the various inputs. Figure 4 shows selection of the starting sub-sampling resolution before image analysis begins. At step 200 the historic data is analysed. For the example of dynamic backlight control, the historic data is a set of bin numbers. For each point in time, a single bin number is stored. The bin number is the number of the bin containing the maximum luminance value which yields an acceptable number of clipped pixels. This represents the optimal backlight value at that time. Some simple ways of analysing the historic data, to get an impression of the dynamic behaviour of the image contents, are to extract the range and the average values of the historic data (bin numbers). The

range is found by extracting the minimum and maximum bin values in the historic data and calculating the difference between them. The average value of the bin number can be found by taking the sum of X bin numbers and dividing by the value X. The analysis can be limited to the most recent data, such as the last 8
5 image frames.

At step 202, the range is compared with a parameter MAXRANGE. This determines how stable the image data is. When the range is below the preset limit of MAXRANGE, the method proceeds, at step 204, to reduce the sampling resolution for this next frame.

10 If the range was above MAXRANGE at step 202, indicating that the image data is dynamic, the method proceeds to step 206. The average value is compared with a parameter MAXAVG. If the average luminance level of the image data is relatively high, i.e. above the preset limit of MAXAVG, the amount of power which can be saved by reducing the backlight intensity is expected to be
15 low and this, in turn, leads to a reduction of the sampling resolution for this next frame at step 204. If the average value is fairly high, indicating that the possible power reduction using dynamic backlight control will be quite low, then a further check is made.

At step 208 the available system resources are checked. If the system
20 resources are low, then the resolution is decreased at step 210. If the system resources are OK, then the sampling resolution can remain at the current value. In this chart the system resources are considered as one combined parameter SYSLOWRESOURCE. As described earlier, the decision can be based on various system resources. If any one of the resources are unacceptably low, the
25 SYSLOWRESOURCE flag can be set high.

Step 208, or an additional step, can compare the amount of system resources expected to be expended in performing the image analysis at the current sub-sampling resolution with a resources budget for the image analysis. If the amount of resources to perform the image analysis is less than the
30 resources budget, the method can proceed at the current sub-sampling resolution. If the amount of resources to perform the image analysis is greater

than the resources budget, the method reduces the sub-sampling resolution. The resources budget can be set as one or more of: a processing resources budget; a memory bandwidth budget; a power budget.

Step 208, or an additional step, can set a power budget for the image analysis as a fraction (e.g. 10%, or some other selected value) of the total amount of power expected to be saved by reducing the backlight intensity. The power budget is compared against an amount of power expected to be expended in performing the image analysis at the current sub-sampling resolution. If the amount of power to perform the image analysis is less than the power budget, the method can proceed at the current sub-sampling resolution. If the amount of power to perform the image analysis is greater than the power budget, the method reduces the sub-sampling resolution.

At step 210, there is a possibility of the sub-sampling resolution being set to zero, which will result in the current image frame being skipped for analysis. At step 212 the analysis of the frame begins, with the selected sub-sampling resolution.

The accuracy of the analysis result will reduce when the sampling resolution is reduced. This means that the difference between intermediate results and the expected result may increase, which would lead to the conclusion that the resolution must be increased again. To avoid a rapid fall back to higher resolutions and to achieve higher levels of power reduction, the variable maxDiff is introduced. This is a design parameter representing the maximum allowed difference between intermediate result and expected result and its value is increased when the sampling resolution is reduced. Figure 5 illustrates this process in more detail, and expands on some of the steps shown in Figure 3. This logic is performed during analysis of a frame of image data.

At step 300 variables are set. There is a starting sub-sampling resolution which has been selected using the method shown in Figure 4. The maximum difference between an intermediate result and an expected result is defined by the parameter maxDiff. The histogram is cleared at step 302 and then the frame of image data is sub-sampled at the starting resolution to construct a histogram

for the frame. An intermediate result is extracted at step 304, and stored as the parameter "tempResult". The result for the current frame (tempResult) is compared with the result for the previous frame (prevResult). If this difference is less than the parameter maxDiff then the current result is considered to be acceptable, and the final result is extracted at step 310. However, if the difference is more than the parameter maxDiff then there may be a need to increase the sub-sampling resolution. At step 312 the system resources are checked. If the system resources are low, which is indicated by the SYSLOWRESOURCE flag being set high, the sub-sampling resolution is not increased. If the system resources are OK, which is indicated by the SYSLOWRESOURCE flag being set low, the sub-sampling resolution is increased at step 314 and the histogram building is continued. The value of the parameter maxDiff can be varied, depending on the starting resolution.

In Figures 4 and 5 the historic data is considered with a higher priority than the system resources, but other schemes could give a higher priority to the availability of system resources, or equal priority could be given to historic data and system resources. Alternatively, only historic data or only system resources are considered.

In Figures 4 and 5 the analysis of the historic data considers range and average value of the most recent historic data, and makes a decision to change the sub-sampling resolution by comparing those parameters with threshold values. Other, more elaborate, forms of statistical analysis can be used to analyse the historic data. For example, it is possible to make a prediction, with a particular certainty, of the next value that will be obtained when the image data is analysed.

Extraction of system control values from histogram.

It is possible to set the backlight at a level which is at least as high as the brightest pixel in the image data (no pixels will be clipped), or to reduce the backlight more aggressively to a level which is lower than a number of pixels in the image data (pixels brighter than the backlight will be clipped). As described

above, one constraint on the dynamic backlight system can be a user input which defines an acceptable level of image quality. The image quality can be defined as a maximum (relative) number of pixels which may be clipped. In a dynamic backlight control which analyses all pixels, the histogram would be normalised, i.e. the bin levels are adjusted (divided by the total number of pixels in the histogram) such that the relative values remain intact and the total sum of bins equals. Then, the normalised bin levels are added, starting from the highest bin, until the sum exceeds the maximum (relative) number of pixels of the control condition. The last bin that was added represents the resulting brightness level of the backlight. A translation from bin number to exact backlight level may be required.

To enable a dynamic selection of the number of pixels to be analysed, the histogram is not normalised (this also saves some processor cycles). This enables the addition of more pixels to the same histogram after an intermediate result is derived from it. Instead, the relative number (e.g. a percentage) from the control condition is translated into an absolute number by multiplication with the currently total amount of pixels in the histogram. The control value for the backlight is then extracted as described above. There are various options for counting the "clipped" pixels. A linear addition adds bin levels with equal weight. A progressive addition weights bins representing brightness levels (which cause a larger error) by an extra penalty factor which is proportional to that error.

Spatial sub-sampling grids

Dynamic sub-sampling can be performed using a set of grids, where each grid defines a different set of pixels, without duplication of pixels, so that the addition of a grid yields a true expansion of the total set of pixels used for the analysis. The grids within a given set can all contain the same number of pixels or they can have different numbers of pixels. A grid can be defined by a set of parameters:

- Horizontal Offset (Hoffset): the number of pixels to skip at the start of each line to select the first pixel to be used for the analysis;

- Horizontal Skip (Hskip): The number of pixels to skip within a line to select the next pixel in that line that must be used for the analysis;
- Vertical Offset (Voffset): the number of lines to skip at the start of a frame to select the first line to be used for the analysis;
- 5 • Vertical Skip (Vskip): the number of lines to skip within a frame to select the next line in that frame that must be used for the analysis.

This is just one example, there are many other ways to define such a grid. Figure 6 shows eight grids (Grid1 – Grid 8) of 4 x 4 sample positions. Each grid is offset spatially from any other grid in the set of grids, such that no two grids
10 have any sampling positions in common. The parameters for these grids are shown in the following table:

	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Grid 7	Grid 8
Hoffset	0	8	0	8	0	8	0	8
Hskip	16	16	16	16	16	16	16	16
Voffset	0	0	4	4	8	8	12	12
Vskip	16	16	16	16	16	16	16	16
factor	256	256	256	256	256	256	256	256

- Figure 7 shows nine grids (Grid1 – Grid 9) of sampling positions, where each grid
15 contains a different number of sampling positions. In this example, Grid 1 comprises the largest grid (an 8 x 16 grid) of sampling positions and other grids contain a decreasing number of sampling positions, with Grid 8 comprising a single sampling position. Each grid is offset spatially from any other grid in the set of grids, such that no two grids have any sampling positions in common. The
20 parameters for these grids are shown in the following table:

	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Grid 7	Grid 8
Hoffset	2	2	4	4	8	8	16	16
Hskip	4	4	8	8	16	16	32	32
Voffset	1	2	2	4	4	8	8	16
Vskip	2	4	4	8	8	16	16	32
factor	8	16	32	64	128	256	512	1024

Other combinations of the grid parameters can be defined to create a multitude of orthogonal sets of sub-sampling grids. Grids of Figure 6 have been found to

yield a more stable behaviour. The grids of Figure 7 may offer a larger average power reduction but with the penalty of less smooth behaviour, similar to loop gain in a feedback control system.

5 A particular sub-sampling resolution can be achieved by using a single grid, or by combining grids. When the sub-sampling resolution needs to be changed, a grid can be added to provide additional sampling positions or a grid can be removed to provide fewer sampling positions.

Although dynamic backlight control has been described above as an application where the method can be used, other applications of the method are:
10 an automatic gain control for an image processing system; a control loop (e.g. in a camera) which adapts the dynamic range of an optical input to the dynamic range of a storage device.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design
15 many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The words "comprising" and "including" do not exclude the presence of other elements or steps than those listed in the claim. Where the system/device/apparatus claims recite several means, several
20 of these means can be embodied by one and the same item of hardware.

The various illustrative logical blocks, modules, circuits, and algorithm steps described above may be implemented as electronic hardware, as software modules executed by a processor, or as combinations of both. Various illustrative components, blocks, modules, circuits, and steps have been described
25 above generally in terms of their functionality. The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable
30 logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the described functions. A general-

purpose processor may be a microprocessor, a conventional processor, a controller, a microcontroller, or a state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more
5 microprocessors in conjunction with a DSP core, or any other such configuration.

A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such that the processor
10 can read information from, and write information to, the storage medium.

In the description above, and with reference to the Figures, there is described a method and apparatus for analysing image data in an image processing system. Image data is sub-sampled at a selected resolution to construct a histogram. The sub-sampling resolution is selected based on at least
15 one of: results of sub-sampling operations on previous frames of the image data; available resources of the image processing system. A comparison is made between an expected control value and an actual control value obtained from sub-sampling at the selected resolution, and the sub-sampling resolution is changed based on the comparison. The method can be applied to dynamic
20 control of the backlight of a display panel. A power budget can be set for the image analysis based on an amount of power which is expected to be saved by reducing the intensity of the backlight.

CLAIMS

1. A method of analysing image data by an image processing system comprising:
 - 5 selecting a resolution for sub-sampling a frame of the image data, wherein the resolution is selectable from a range of different resolutions;
sub-sampling a characteristic of the frame of image data at the selected sub-sampling resolution; andwherein the selection of the sub-sampling resolution is based on at least one of:
 - 10 results of sub-sampling operations on previous frames of the image data;
resources of the image processing system.
2. A method according to claim 1 wherein the selection of the sub-sampling resolution based on resources of the image processing system comprises:
 - 15 setting a system resources budget for analysing the image data and the selection of the sub-sampling resolution is based on a comparison of resources required to perform the analysis of the image data with the system resources budget.
- 20 3. A method according to claim 2 wherein the system resources budget comprises at least one of: a processing resources budget; a memory bandwidth budget; a power budget.
4. A method according to any one of the preceding claims wherein the selection of the sub-sampling resolution is based on an amount of resources of the image processing system which are available.
- 25 5. A method according to any one of the preceding claims further comprising determining if the sub-sampling resolution is sufficient and, when the sub-sampling resolution is not sufficient, increasing the sub-sampling resolution.
- 30

6. A method according to claim 5 wherein the sub-sampling resolution is increased by sub-sampling the frame of image data at other sub-sampling positions, and combining the results of the multiple sub-sampling operations of the frame of image data.

5

7. A method according to claim 5 or 6 wherein the sub-sampling resolution is increased iteratively until the sub-sampling resolution is sufficient.

8. A method according to any one of claims 5 to 7 wherein the step of
10 determining if the sub-sampling resolution is sufficient comprises determining an actual control value based on the results of the sub-sampling, and determining an expected control value based on results of sub-sampling operations on previous frames of image data.

15 9. A method according to any one of the preceding claims wherein the sub-sampling has a set of possible sampling grids which define which elements of the image data will be used in the sub-sampling, wherein the set of sampling grids are spatially offset from one another.

20 10. A method according to any one of the preceding claims wherein the sub-sampling is performed at different spatial positions of sequential image frames.

11. A method according to any one of the preceding claims wherein the
25 characteristic of the image data is a luminance value of an element of the image data.

12. A method of controlling intensity of a backlight of a display comprising:
analysing image data using the method of any one of the preceding
claims, wherein the characteristic of the image data is a luminance value of an
30 element of the image data;

determining a backlight intensity value based on maximum luminance values in the sub-sampled data.

13. A method according to claim 12 wherein the sub-sampling resolution is
5 lowered or maintained at the same resolution as a sub-sampling operation on a previous frame if results of previous frames indicate that the backlight intensity cannot be reduced below a predefined threshold.

14. A method according to claim 12 or 13 further comprising setting a power
10 budget for the image analysis, wherein the power budget is based on an amount of power expected to be saved by reducing the backlight intensity, and wherein the sub-sampling resolution is selected such that the amount of power required to perform the image analysis is less than the power budget.

15. A method according to claim 14 wherein the power budget is set at a
15 fraction of the amount of power expected to be saved by reducing the backlight intensity.

16. A processing apparatus which is arranged to perform the method
20 according to any one of the preceding claims.

17. Software for causing a processing apparatus to perform the method according to any one of claims 1 to 15.

25 18. A image processing system comprising:
an image processing device; and,
a processing apparatus which is arranged to perform the method according to any one of claims 1 to 15.

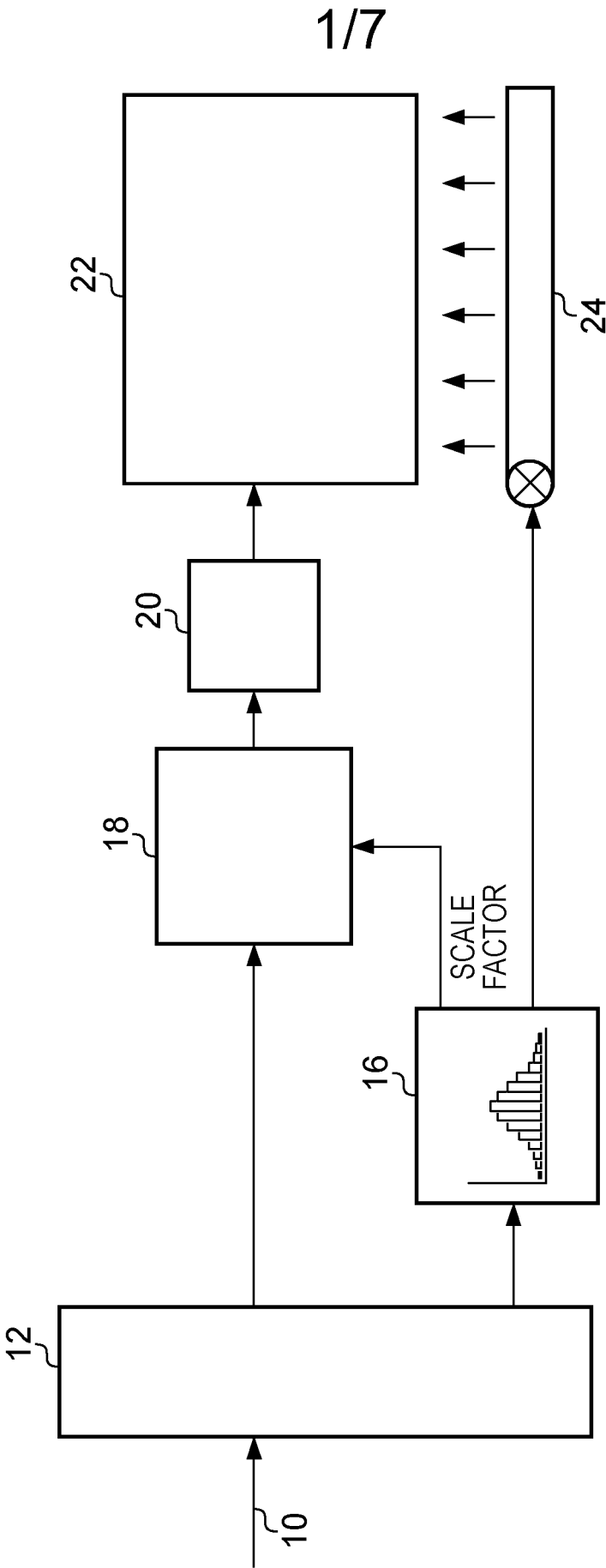


FIG. 1

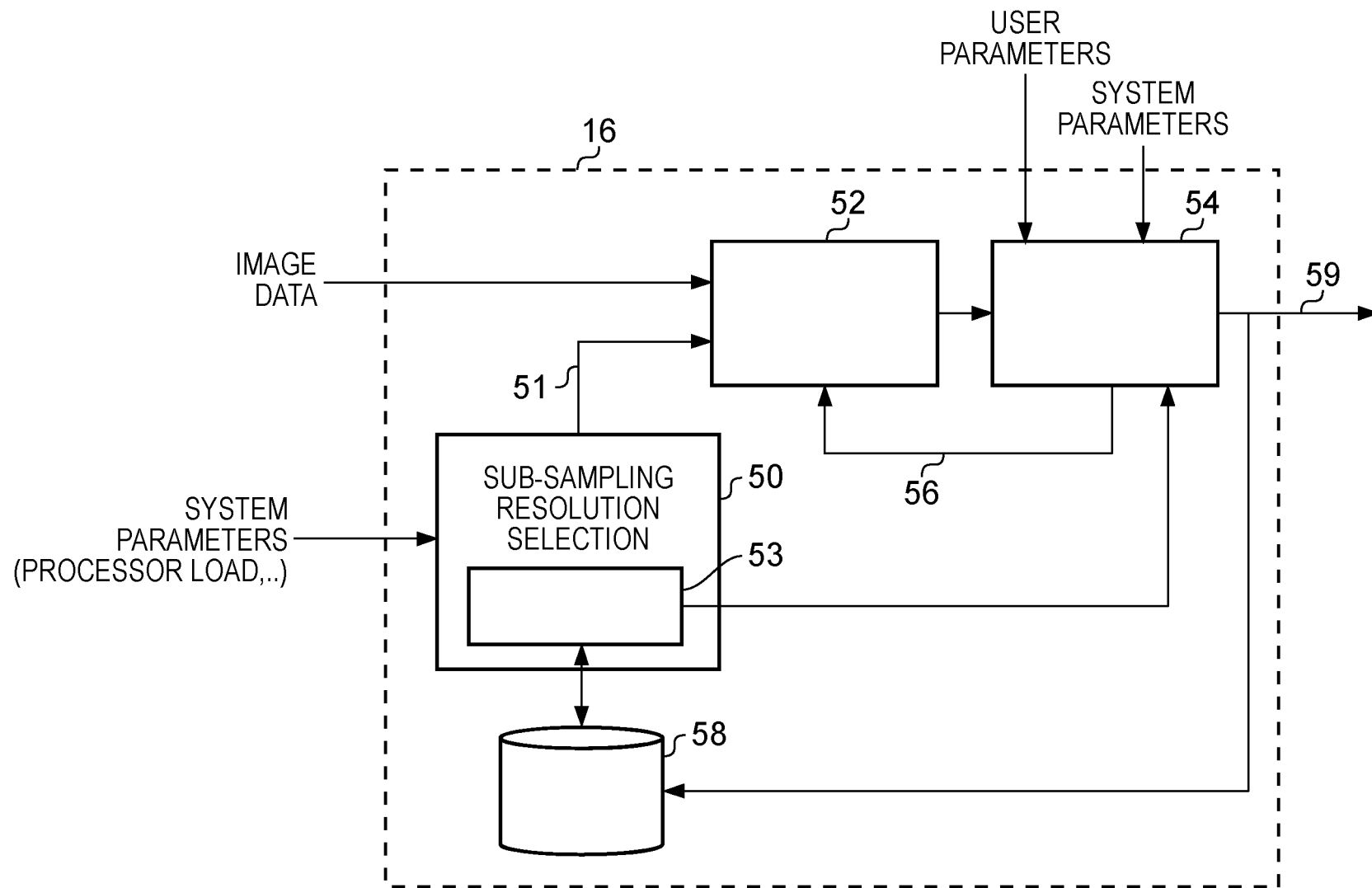


FIG. 2

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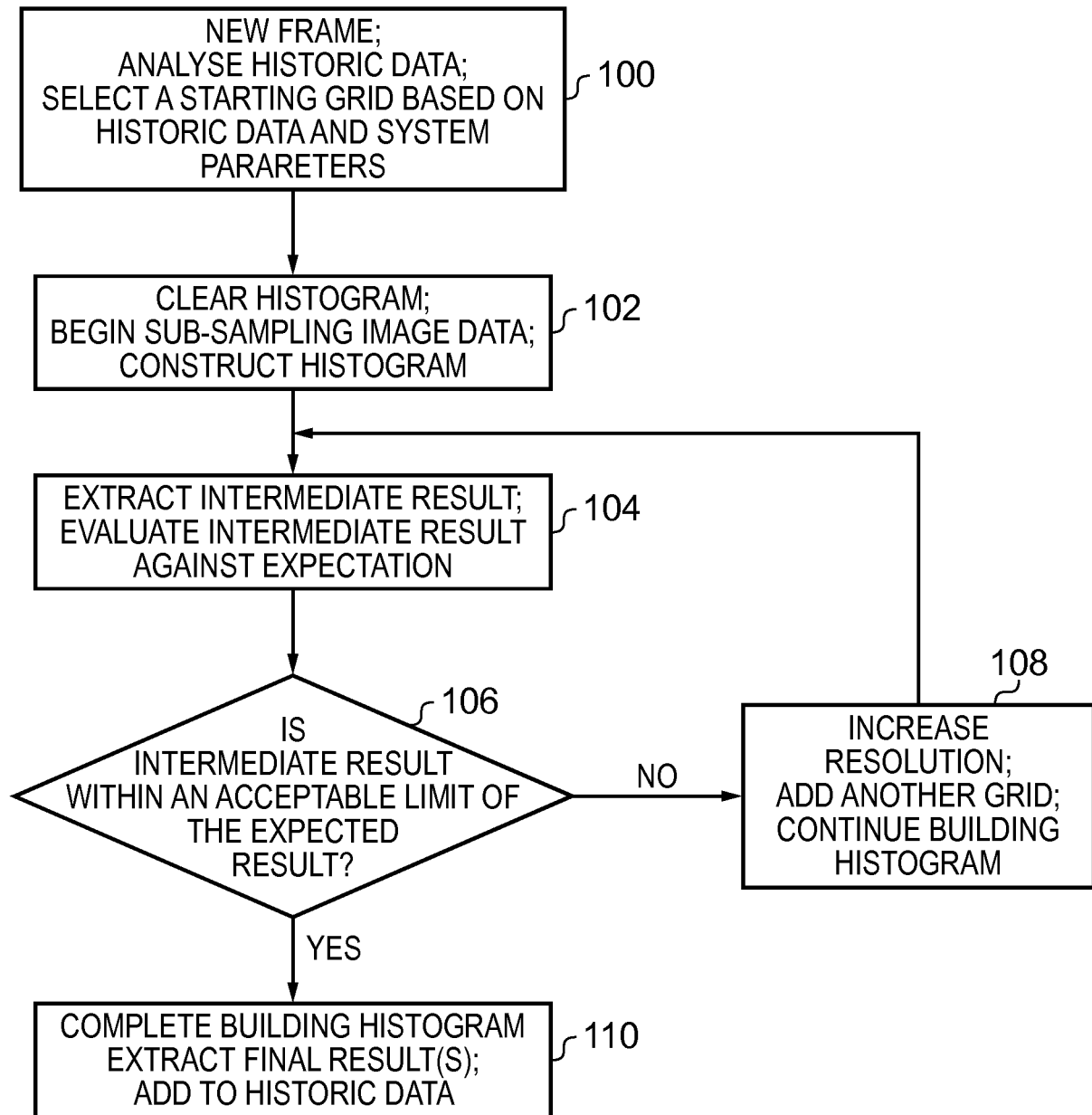


FIG. 3

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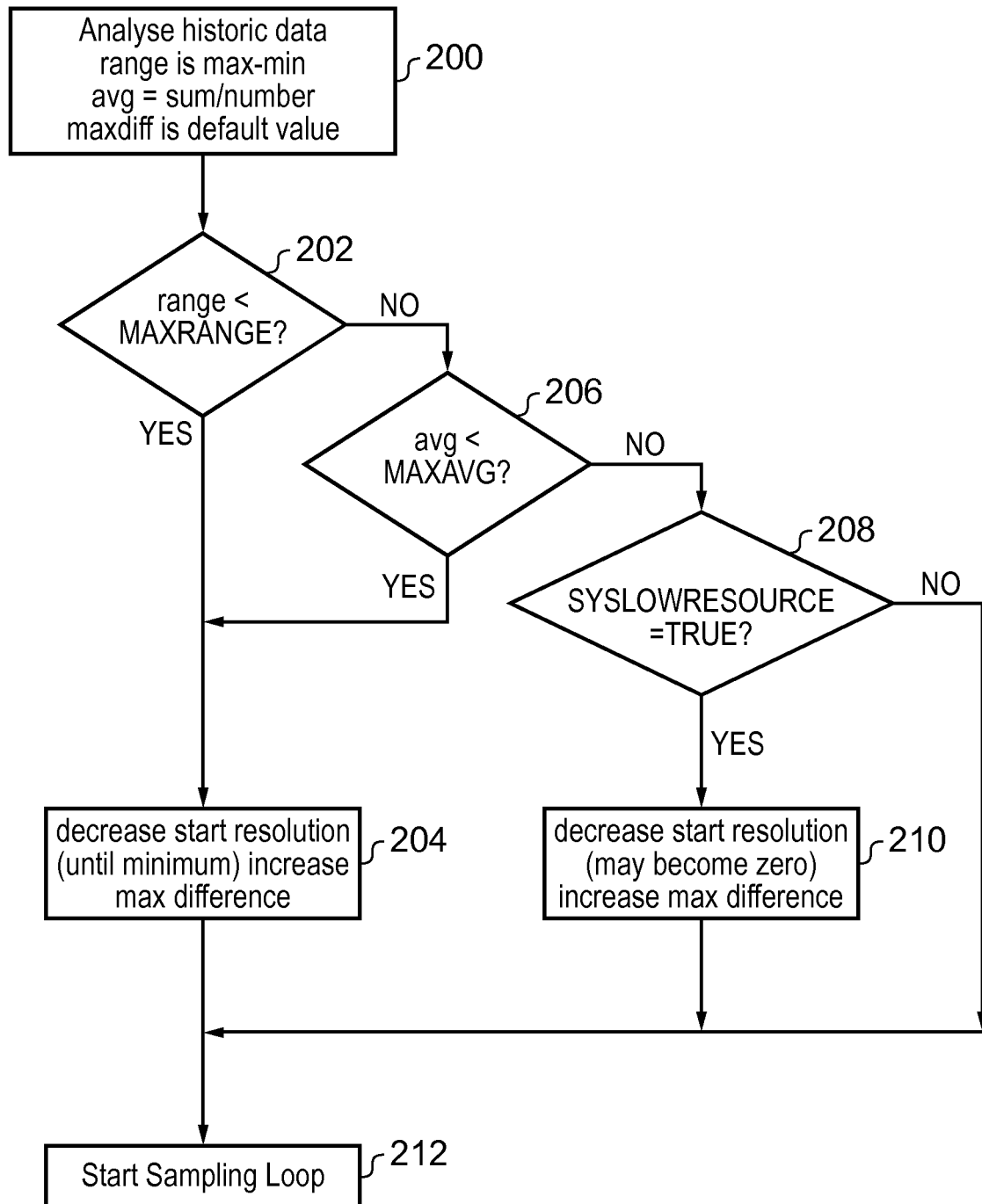


FIG. 4

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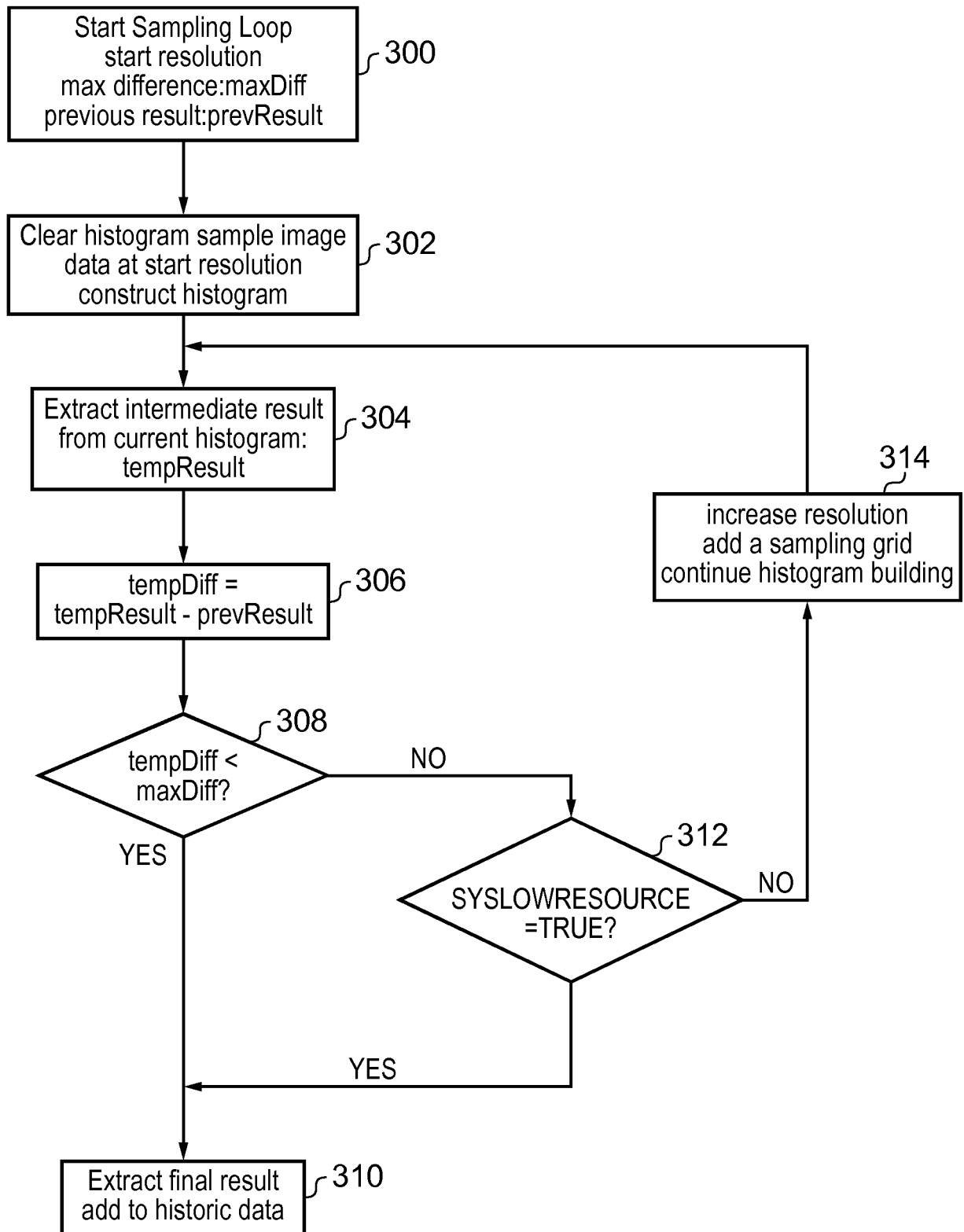


FIG. 5

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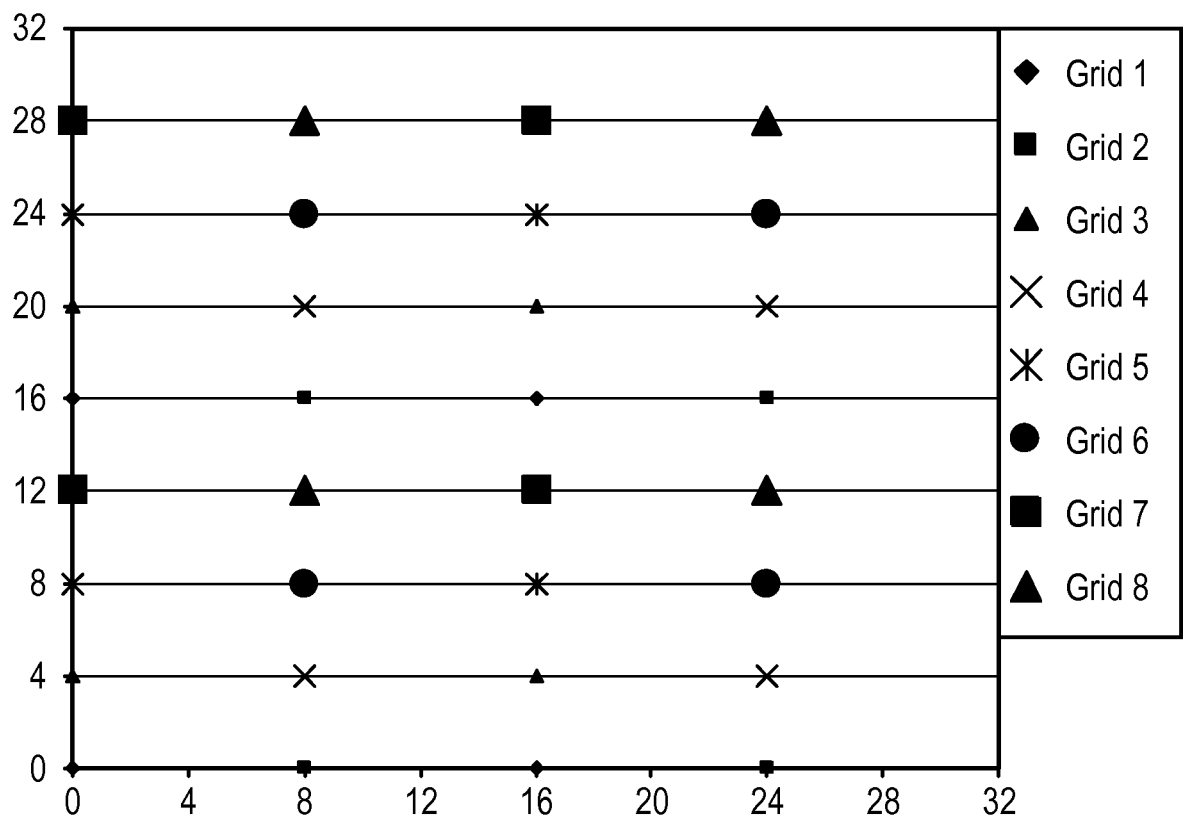


FIG. 6

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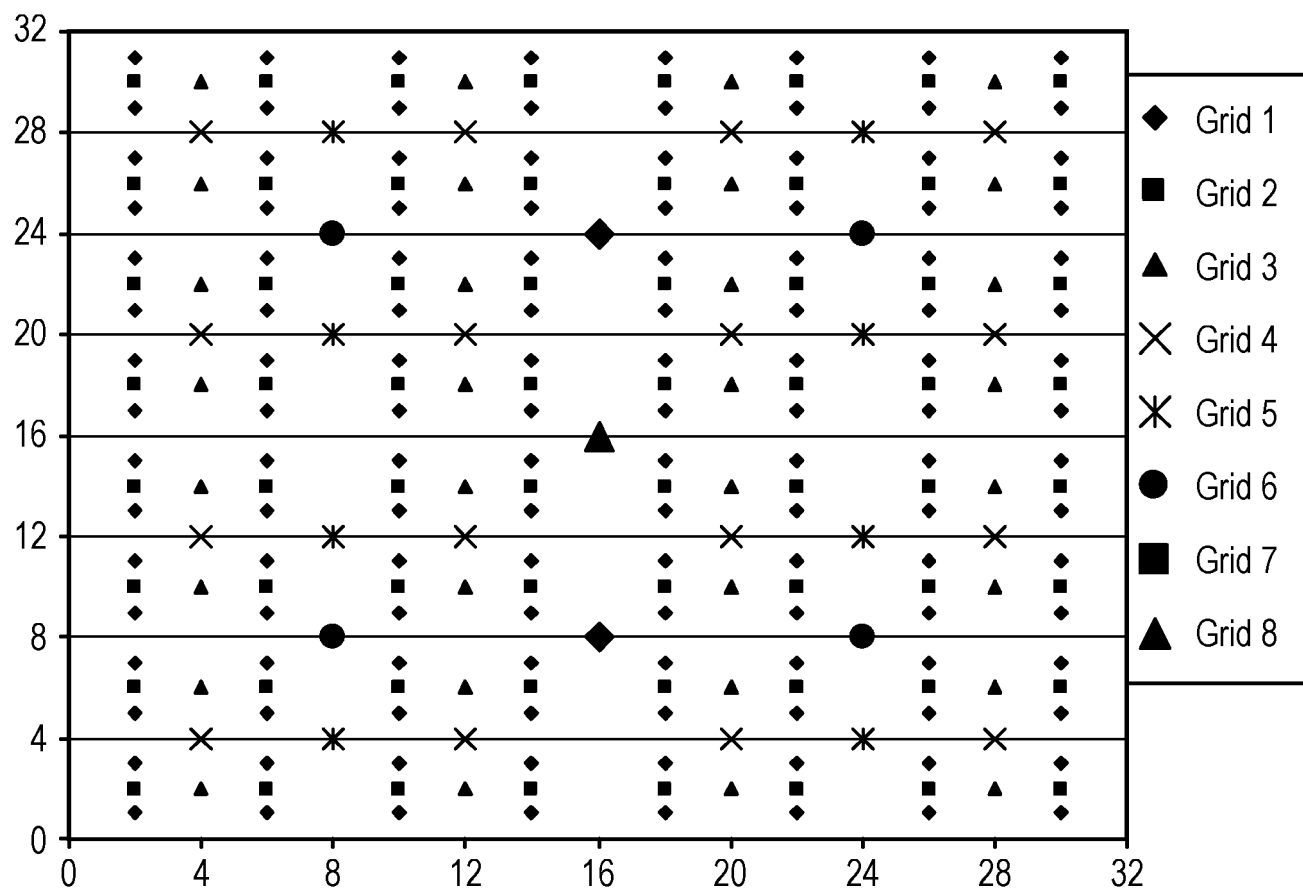


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2009/053878

A. CLASSIFICATION OF SUBJECT MATTER

INV. G06T3/40

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)

G06T G09G

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/183678 A1 (SANKAR ANANTH [US] ET AL) 9 August 2007 (2007-08-09) column 1 - column 4 figure 1	1-8, 11-18
A	----- TZOU K-H: "PROGRESSIVE IMAGE TRANSMISSION: A REVIEW AND COMPARISON OF TECHNIQUES" OPTICAL ENGINEERING, SOC. OF PHOTO-OPTICAL INSTRUMENTATION ENGINEERS, BELLINGHAM, vol. 26, no. 7, 1 July 1987 (1987-07-01), pages 581-589, XP002065700 ISSN: 0091-3286 page 581 - page 582 page 585 - page 587 ----- -/--	6,7

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

16 December 2009

Date of mailing of the international search report

23/12/2009

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Katsoulas, Dimitrios

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2009/053878

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CHEE Y-K: "SURVEY OF PROGRESSIVE IMAGE TRANSMISSION METHODS" INTERNATIONAL JOURNAL OF IMAGING SYSTEMS AND TECHNOLOGY, WILEY AND SONS, NEW YORK, US, vol. 10, no. 1, 1 January 1999 (1999-01-01), pages 3-19, XP000805935 ISSN: 0899-9457 page 3 - page 4 page 13 - page 14 figure 12	6,7
A	----- SLOAN K R ET AL: "PROGRESSIVE REFINEMENT OF RASTER IMAGES" IEEE TRANSACTIONS ON COMPUTERS, IEEE SERVICE CENTER, LOS ALAMITOS, CA, US, vol. C-28, no. 11, 1 November 1979 (1979-11-01), pages 871-875, XP000827809 ISSN: 0018-9340 page 1; figure 1	6,7
A	----- PANUSOPONE K ET AL: "Progressive image transmission by refining sampling lattice" SIGNALS, SYSTEMS AND COMPUTERS, 1996. CONFERENCE RECORD OF THE THIRTIETH ASILOMAR CONFERENCE ON PACIFIC GROVE, CA, USA 3-6 NOV. 1996, LOS ALAMITOS, CA, USA, IEEE COMPUT. SOC, US, 3 November 1996 (1996-11-03), pages 1294-1298, XP010231356 ISBN: 978-0-8186-7646-8 page 1294 - page 1295	6,7
A	----- BELFOR R A F ET AL: "Spatially adaptive subsampling of image sequences" IEEE TRANSACTIONS ON IMAGE PROCESSING, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 3, no. 5, 1 September 1994 (1994-09-01), pages 492-500, XP002534817 ISSN: 1057-7149 page 492 page 495 - page 497 figure 4	6,7

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2009/053878

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007183678 A1	09-08-2007	WO 2008016459 A2	07-02-2008