

SPECIFICATION

Video signal processing

- 5 The present invention relates to processing circuitry for discrete-sample type colour video signals and, more particularly, to circuitry which reduces artifacts of sampling.

The conversion of a colour image to an electrical signal representation by elemental area-type imagers, such as charge transfer imaging devices, is known. One of the problems which arises when information is extracted as discrete samples from such imagers is that the colour signals tend to exhibit sharp transitions at the boundaries of the picture sensing elements and colour banding effects occur. Signal processing of these sharp transitions results in a loss of image detail. The aforementioned problem with signal characteristics is even more significant when colour imaging is performed on a "single chip" because the transitions are staggered among the colours and the sampling frequency may vary with colour. U.S. Patent No. 3,971,065 discloses a sensing array for colour imaging having luminance (green) and chrominance (blue, red) sensitive elements so intermixed that each type of element occurs in a repeated pattern with luminance elements dominating the array.

One known technique for removing the artifacts arising from discrete sampling is to smooth the video signal by applying it to a low-pass filter, albeit with the undesirable loss of high-spatial frequency image detail.

In accordance with the present invention there is provided a signal processing apparatus for use with a video camera including an imaging device having rows of elements with a repeating pattern of red, blue and green colour sensitivities, and readout means for interrogating the elements on a row by row basis to produce a signal representing sample levels for the respective colours, the apparatus comprising decoding means arranged to receive the sample signals and to generate therefrom pulse signals, and an interpolator arranged to receive the pulse signals and to produce therefrom continuous red, blue and green signals, including respective colour signal delays having a time delay matched to the sampling rates for the corresponding colour signal and respective integrators for integrating the difference between the delayed and the undelayed corresponding colour signal for producing a continuous colour signal.

There is also provided a video camera including a signal processing apparatus as above.

The invention will now be described, by way of example with reference to the accompanying drawings wherein;

Figure 1 is a block diagram illustrating apparatus with which the signal processing circuitry of the present invention may be used;

Figure 2 is a timing diagram indicating the operation of a demultiplexer used in conjunction with the apparatus of *Figure 1*;

Figure 3 indicates a preferred colour sampling pattern of an elemental image sampler for use with

the present invention;

Figure 4 is a diagram in block form of a signal processing circuit according to the present invention;

Figure 5A is a block diagram of an interpolation circuit for use in the present invention;

Figure 5B is a set of graphs showing the operation of the interpolator circuit shown in *Figure 5A*;

Figure 6 is a block diagram of an edge enhancement circuit for use with signal processing apparatus as described and claimed in Application No. 8011388 which is divided from the present application; and

Figure 7 depicts a set of waveforms produced during the operation of the circuit shown in *Figure 6*.

Referring to *Figure 1* a discrete area image sampler 10, which may, for example, include one or more charge-transfer-type imagers, produces a video signal set *C*. Assuming a time-division-multiplexed set of signals for green, red, and blue (denoted *G*, *R* and *B*, respectively) a demultiplexer 12 produces individual pulse or "discrete sample" type signals for such colours (dashed lines serving to indicate additional channels for "partial sample population demultiplexing" as is discussed below). The demultiplexer may comprise a series of sample-and-hold circuits and a simplified timing diagram for such circuits is indicated in *Figure 2*, *S_G*, *S_R*, *S_B* denoting "sample green", "sample red", and "sample blue", respectively. The separated colour signal samples (see the last three graphs of *Figure 2*) are applied to a signal processor 14 where the colour signal samples are modified. The image sampler 10, the demultiplexer 12 and the signal processor 14 are controlled by a clock 2. One imager sampling pattern for use in providing the video signal set *C* is shown in *figure 3*, which pattern includes green samples at twice the rate of red or blue samples. A technique which exploits the resulting non-uniform colour sample rates is explained below.

Referring to *Figure 4*, a signal processing apparatus 11 cooperates with an image sampler 10, having a sampling pattern as shown in *Figure 3*, which produces a time-division-multiplexed signal having green, red and blue image sample information intermixed.

The sampling is controlled by a clock 2', controlling readout circuitry 4 coupled to the image sampler 10.

A demultiplexer 12' (primes being used to indicate particular implementations of elements already discussed generally) receives the sampled image signal and using sample-and-hold circuits 20 generates a set of five discrete-time colour signals, a "full" green signal based on all of the green samples (*G_F*); a red signal based on all of the red samples (*R*); a blue signal based on all of the blue samples (*B*); a first "slow" green signal based on every other green sample (*G_{S2}*) based on the green samples omitted for the first slow green signal. Synchronization of the sampling is achieved by the use of clocking pulses.

The discrete-time colour signals are supplied to a signal processing circuit 14' which produces output colour signals $\hat{R}$, $\hat{B}$, $\hat{G}$. Signal upgrading by means of an interpolation process may be performed by integrating differences between adjacent samples

for the respective discrete colour signals as mentioned above. Higher order interpolation may be advantageous. An interpolating apparatus 40 is included in each of the signal channels except the channel for the full green signal G_F where interpolation is combined with an edge enhancement operation as discussed below. Each interpolating apparatus 40 shown in more detail in Figure 5A includes a delay 42, the delay α of which corresponds to the period for the respective discrete-time colour signal. An analogue shift-register may be used for the delay device 42 and then a clocking signal input Φ will be required, derived from the main clock 2 in a shift and sampling clock 6.

A difference circuit 43 has inputs of the relatively undelayed signal and the signal by the delay 42. The output of the difference circuit is fed to an integrator 44 which produces a signal representing the integrated difference between the delayed and the relatively undelayed version of the discrete-time colour signal. At the end of each row of signal image information, the integrator 44 is reset to zero level. By integrating sample-to-sample differences along a row in this manner the output signal of the integrator 44 is caused to represent a first order linear interpolation between colour sample levels (see Figure 5B which shows typical waveforms occurring in the interpolating apparatus 40).

In the signal processing circuit 14', the "slow" green signals G_{S1} and G_{S2} are averaged in a summing device 50 and the average "slow" green signal is subtracted from the "full" green signal G_F in a summing device 52 to produce a signal $\hat{Y}_H$ representing high frequency luminance. A proportion β of the signal ($\hat{Y}_H$), tapped from a potentiometer 53, is added to the red and blue and average "slow" green signals at summers 56, 58 and 60, respectively. By sampling the green colour component (the primary colour component most closely corresponding to luminance) at the higher rate, a detailed high frequency luminance signal is provided for addition to all three primary colour signals. For the high frequency component of all three colour signals the highest sampling rate information is used whereas the low sampling rate information for the respective colours is used to develop the low frequency colour signal components. By adding the luminance signal to all three colour signals whereby the high frequency detail is neutral, undesirable colour banding effects at edges are reduced or obviated. While the "full" green channel might have been used as the output signal $\hat{G}$, the use of summers 56, 58, 60 facilitates colour matrixing, matrixing coefficients (β subscript) being indicated for the signal inputs to the summers 56, 58, 60.

In a preferred embodiment of the invention the "full"-green signal is made more effective as the signal for representing high frequency detail by producing a weighted average of adjacent samples. An enhancement circuit 62 incorporates an interpolation of the type provided by the apparatus 40 discussed above and is indicated in the "full"-green signal channel in Figure 4. The enhancement circuit 62 includes delays 64, 66 and 68 which are matched to the sampling period for the "full" green signal.

Again, analogue shift registers may be used to provide the delays and clocking signals G thereto have been indicated. The objective of processing by the circuit 62 is to modify the undelayed signal and the delayed signals by various weighting coefficients. Such weighting coefficients are empirically chosen to provide the best apparent picture quality. In Figure 4, a weighting of adjacent samples to enhance high frequencies and an interpolation (along the lines provided by the circuit 40) are "combined" in the circuit 62 using the gains shown at a summing device 70 and a summing device 72, in conjunction with the scaling $\alpha/2$ of a potentiometer 73. The output of device 72 is supplied to an integrator 74 which produces the enhanced full-green signal. The preferred configuration for circuit 62 has the special advantage of concentrating adjustment of the empirical coefficient α at a single point, namely the potentiometer. Regardless of whether the interpolation and enhancement are "combined", as in Figure 4, or separately implemented, it will be appreciated that the heart of the enhancement process is the algebraic summing of a delayed signal with both a signal of longer delay or delays and with an undelayed signal. In this regard, it will be further appreciated, from the waveforms associated with the leads of Figure 4, that the signal appearing at the output of the summing amplifier 52 is an enhanced signal.

In Figure 6, with the associated waveforms being shown in Figure 7, is illustrated a preferred embodiment of the circuit 62. The undelayed signal $G(t)$ is fed to two delays 200, 202 in succession, giving a once delayed signal $G(t-\delta)$. The undelayed signal $G(t)$ and the twice delayed signal $G(t-2\delta)$ are fed to inputs of an operational amplifier 204 which applies a weight factor $-\alpha/2$ in each case. The once delayed signal $G(t-\delta)$ is fed to a further input of the amplifier 204 which applies a weighting factor $(1+\alpha)$. The output of the amplifier is then fed to an interpolation circuit 206 to give the "enhanced" green signal $G_H(t)$.

CLAIMS

1. A signal processing apparatus for use with a video camera including an imaging device having rows of elements with a repeating pattern of red, blue and green colour sensitivities, and readout means for interrogating the elements on a row by row basis to produce a signal representing sample levels for the respective colours, the apparatus comprising decoding means arranged to receive the sample signals and to generate therefrom pulse signals, and an interpolator arranged to receive the pulse signals and to produce therefrom continuous red, blue and green signals, including respective colour signal delays having a time delay matched to the sampling rates for the corresponding colour signal and respective integrators for integrating the difference between the delayed and the undelayed corresponding colour signal for producing a continuous colour signal.

2. An apparatus as claimed in Claim 1, wherein the green sample rate is twice that of the blue and red sample rates, wherein the decoding is arranged



for the respective discrete colour signals as mentioned above. Higher order interpolation may be advantageous. An interpolating apparatus 40 is included in each of the signal channels except the 5 channel for the full green signal G_F where interpolation is combined with an edge enhancement operation as discussed below. Each interpolating apparatus 40 shown in more detail in Figure 5A includes a delay 42, the delay α of which corresponds to the 10 period for the respective discrete-time colour signal. An analogue shift-register may be used for the delay device 42 and then a clocking signal input Φ will be required, derived from the main clock 2 in a shift and sampling clock 6.

15 A difference circuit 43 has inputs of the relatively undelayed signal and the signal by the delay 42. The output of the difference circuit is fed to an integrator 44 which produces a signal representing the integrated difference between the delayed and the 20 relatively undelayed version of the discrete-time colour signal. At the end of each row of signal image information, the integrator 44 is reset to zero level. By integrating sample-to-sample differences along a row in this manner the output signal of the integrator 25 44 is caused to represent a first order linear interpolation between colour sample levels (see Figure 5B which shows typical waveforms occurring in the interpolating apparatus 40).

In the signal processing circuit 14', the "slow" 30 green signals G_{S1} and G_{S2} are averaged in a summing device 50 and the average "slow" green signal is subtracted from the "full" green signal G_F in a summing device 52 to produce a signal $\hat{Y}_H$ representing high frequency luminance. A proportion β of the 35 signal ($\hat{Y}_H$), tapped from a potentiometer 53, is added to the red and blue and average "slow" green signals at summers 56, 58 and 60, respectively. By sampling the green colour component (the primary colour component most closely corresponding to 40 luminance) at the higher rate, a detailed high frequency luminance signal is provided for addition to all three primary colour signals. For the high frequency component of all three colour signals the highest sampling rate information is used whereas 45 the low sampling rate information for the respective colours is used to develop the low frequency colour signal components. By adding the luminance signal to all three colour signals whereby the high frequency detail is neutral, undesirable colour banding 50 effects at edges are reduced or obviated. While the "full" green channel might have been used as the output signal $\hat{G}$, the use of summers 56, 58, 60 facilitates colour matrixing, matrixing coefficients (β subscript) being indicated for the signal inputs to the 55 summers 56, 58, 60.

In a preferred embodiment of the invention the "full"-green signal is made more effective as the signal for representing high frequency detail by producing a weighted average of adjacent samples. 60 An enhancement circuit 62 incorporates an interpolation of the type provided by the apparatus 40 discussed above and is indicated in the "full"-green signal channel in Figure 4. The enhancement circuit 62 includes delays 64, 66 and 68 which are matched 65 to the sampling period for the "full" green signal.

Again, analogue shift registers may be used to provide the delays and clocking signals G thereto have been indicated. The objective of processing by the circuit 62 is to modify the undelayed signal and the delayed signals by various weighting coefficients. Such weighting coefficients are empirically chosen to provide the best apparent picture quality. In Figure 4, a weighting of adjacent samples to enhance high frequencies and an interpolation 70 (along the lines provided by the circuit 40) are "combined" in the circuit 62 using the gains shown at a summing device 70 and a summing device 72, in conjunction with the scaling $\alpha/2$ of a potentiometer 73. The output of device 72 is supplied to an 80 integrator 74 which produces the enhanced full-green signal. The preferred configuration for circuit 62 has the special advantage of concentrating adjustment of the empirical coefficient α at a single point, namely the potentiometer. Regardless of whether 85 the interpolation and enhancement are "combined", as in Figure 4, or separately implemented, it will be appreciated that the heart of the enhancement process is the algebraic summing of a delayed signal with both a signal of longer delay or delays and with 90 an undelayed signal. In this regard, it will be further appreciated, from the waveforms associated with the leads of Figure 4, that the signal appearing at the output of the summing amplifier 52 is an enhanced signal.

95 In Figure 6, with the associated waveforms being shown in Figure 7, is illustrated a preferred embodiment of the circuit 62. The undelayed signal $G(t)$ is fed to two delays 200, 202 in succession, giving a once delayed signal $G(t-\delta)$. The undelayed signal 100 $G(t)$ and the twice delayed signal $G(t-2\delta)$ are fed to inputs of an operational amplifier 204 which applies a weight factor $-\alpha/2$ in each case. The once delayed signal $G(t-\delta)$ is fed to a further input of the amplifier 204 which applies a weighting factor $(1+\alpha)$. The 105 output of the amplifier is then fed to an interpolation circuit 206 to give the "enhanced" green signal $G_H(t)$.

CLAIMS

110 1. A signal processing apparatus for use with a video camera including an imaging device having rows of elements with a repeating pattern of red, blue and green colour sensitivities, and readout means for interrogating the elements on a row by 115 row basis to produce a signal representing sample levels for the respective colours, the apparatus comprising decoding means arranged to receive the sample signals and to generate therefrom pulse signals, and an interpolator arranged to receive the 120 pulse signals and to produce therefrom continuous red, blue and green signals, including respective colour signal delays having a time delay matched to the sampling rates for the corresponding colour signal and respective integrators for integrating the 125 difference between the delayed and the undelayed corresponding colour signal for producing a continuous colour signal.

2. An apparatus as claimed in Claim 1, wherein the green sample rate is twice that of the blue and 130 red sample rates, wherein the decoding is arranged



to produce a full green signal based on all the green samples, a red signal based on all the red samples, a blue signal based on all the blue samples and at least one 'slow green' signal based on a fraction of the green samples.

3. An apparatus as claimed in Claim 2, having two 'slow green' signal interpolators, each comprising a delay and an integrator, and control means for directing green signal samples alternately to each 'slow green' signal interpolator, and averaging means for averaging the signals output from the two 'slow green' signal interpolators.

4. An apparatus according to Claim 3 further comprising a matrix for subtracting the output from the averaging means from the full green signal for producing a luminance related signal for relatively high spatial frequencies, and means for adding the luminance related signal to the interpolated red, blue and 'slow green' signals to produce red, blue and green outputs.

5. An apparatus as claimed in any one of the preceding claims, further including processing means comprising first and second delays for time delaying the green sample signals by a first time and by a second longer time and signal combining means arranged to receive the undelayed signals which are applied to the processing means and signals delayed by the first and second delays, so as to sum the undelayed signals and the signals delayed by the second delay and to subtract the sum signals so produced from the signals which are delayed by the first delay to produce resultant signals which are enhanced versions of the signals corresponding to the image representative pulse signals.

6. An apparatus as claimed in Claim 5 wherein the first and second delay times correspond, respectively, to first and second multiples of the sampling period of the colour signal.

7. An apparatus as claimed in Claim 6, wherein the signal combining means provides greater gain to the signals from the first delay than to the other signals applied thereto.

8. A signal processing device as claimed in Claim 1, and substantially as hereinbefore described, with reference to and as illustrated in the accompanying drawings.

9. A video camera including an imaging device having rows of elements with repeating patterns of red, blue and green colour sensitivities and readout means for interrogating the elements on a row-by-row basis to produce a signal representing sample levels for the respective colours, and further including a signal processing apparatus as claimed in any preceding Claim.

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