

PHASE MOTION DETECTOR FOR BASEBAND YC SEPARATION

Field of the Invention

[0001] The present invention generally relates to video signal processing, and more particularly to a phase motion detector for baseband YC separation for image quality improvement.

Background of the Invention

[0002] In composite video television systems such as NTSC and PAL, luminance and chrominance information share a portion of the total signal bandwidth. While clean separation between luminance and chrominance is highly desired, current video signal decoders misinterpret the shared luminance and chrominance information, resulting in cross color and dot crawl. Both are highly disturbing artifacts. The term “cross color” refers to corruption of the chrominance spectrum caused by the misinterpretation of high-frequency luminance information as chrominance information. Cross color manifests itself in spectrum of bright colors changing from frame to frame. Conversely, the term “dot crawl” or “cross luminance” refers to corruption of the luminance spectrum by the misinterpretation of chrominance information as high-frequency luminance information. Dot crawl manifests itself in patterned high amplitude noise.

[0003] Both artifacts can be reduced by selectively filtering video signals during signal processing. The filtering process usually employs a 3D comb filter comprising at least one line comb filter and at least one frame comb filter. A line comb filter can reduce such artifacts but its effectiveness is limited to artifacts generated by vertical edges and it has a disadvantage of decreasing the vertical resolution. A frame comb filter, on the other hand, provides maximum picture resolution but can only be applied to stationary parts of a picture. To maximize the effectiveness of the comb filters, a highly precise motion detector that can differentiate between the moving and stationary pixels is required.

[0004] Conventional arts use a low pass inter-frame difference to generate a motion map to select line comb filters when motion is detected and frame comb filters when there is no motion. Depending on the cut-off frequency of the low pass filter, the performance of

the 3D comb filter varies. If the cut-off frequency is high, some motion due to cross luminance may be falsely detected and the 3D comb filter's effectiveness is reduced. If the cut-off frequency is low, motion with higher frequency content may not be detected and motion smearing results. The higher the overlapping of the chrominance with video bandwidth, the more ineffective the motion detection.

[0005] Some have improved the performance of motion detection by associating oblique correlation with likelihood of false motion. One disclosed motion detection device including an oblique correlation detection section, motion detection section and motion determination section decreases the sensitivity of motion detection in the presence of an oblique correlation. However, the implementation of the concept using decreased sensitivity in presence of oblique correlation is not sufficient because of the conflict of interests. On one hand, the decreased sensitivity may have impaired the detection of true motion for oblique objects. On the other hand, decreased sensitivity may not be sufficient to prevent false motion detection in mixed color/luminance edges since cross luminance are typically of large amplitudes.

[0006] Another example for motion detection uses a plurality of temporal pixels to determine the motion or still status of the video composite signal suitable for use in a 3D comb filter in video decoder. Yet another example for motion detection uses a motion detection circuitry with precise Y motion and C motion detection. The Y motion detection uses the frame difference of line-comb Y signal with chroma level and vertical edge consideration. The C motion detection uses the frame difference of line-comb C signal, together with the frame difference of composite signal and chroma vertical and horizontal correlation computed from the frame-comb Y signals of adjacent lines. Yet another example for motion detection uses a two-frame difference signal that has been filtered to remove chrominance information. The filtering is performed on at least one spatial axis according to the spatial correlation. Although this motion detection considers the contributions from both luminance and chroma, it does not represent the temporal difference between the frames being filtered.

[0007] FIG 13 shows an exemplary functional block diagram of a motion detector of a conventional 3D comb filter. As to the NTSC standard, an approximate luminance data is obtained after the composite video signal has passed through a low pass filter, and a luminance data of the previous frame is obtained after the approximate luminance data

has been delayed by a frame buffer for a frame time. The luminance data of the current frame is then compared with the luminance data of the previous frame so as to obtain a luminance difference. In addition, a chrominance data is obtained after the composite video signal has passed through a band pass filter and has been subtracted from the luma data. Then the chrominance data of the previous two frames is obtained after the chrominance data has been delayed by the frame buffers for two frame time. A chrominance difference is obtained after the chrominance data of the current frame is subtracted from the chrominance data of the previous two frames. A detecting circuit calculates a motion factor by selecting a number which is bigger between the luminance difference and the chrominance difference.

[0008] Generally, these methods do not consider motion contributed by chroma component because of interfering high frequency luminance at chroma band. However, there exists motion with purely color motion and a misdetection results in color smearing.

[0009] Hence, there is a need to detect true luminance and chroma motions, especially chroma-only motion and high frequency luminance motion. Furthermore, the motion detection problem in baseband is more challenging than in composite domain in that there are 3 corrupted component inputs not guaranteed to be generated by complementary decoders.

Brief Description of the Drawings

[0010] Preferred embodiments according to the present invention will now be described with reference to the Figures, in which like reference numerals denote like elements.

[0011] FIG 1 is a functional block diagram of the circuitry of the motion detection system for the NTSC standard in accordance with one embodiment of the present invention.

[0012] FIG 2 shows exemplary electric circuitries for the luminance motion detector **101**, the chrominance motion detectors **102/103**, the smoothness detectors **104/105**, and the phase motion detectors **106/107** in accordance with one embodiment of the present invention.

[0013] FIG 3 shows an exemplary circuitry of the motion detector for NTSC standard in accordance with another embodiment of the present invention.

[0014] FIG 4 is a functional block diagram showing a baseband YC separation circuitry in accordance with one embodiment of the present invention.

[0015] FIG 5 shows an exemplary circuit of the cross luminance suppression circuit **2001** for the NTSC standard in accordance with one embodiment of the present invention.

[0016] FIG 6, there is provided an exemplary circuit of the cross chroma suppression circuits **2002/2003** in accordance with one embodiment of the present invention.

[0017] FIG 7 is a functional block diagram of a video signal processing system in accordance with one embodiment of the present invention.

[0018] FIG 8 is a functional block diagram of the circuitry of the motion detection system for the PAL standard in accordance with one embodiment of the present invention.

[0019] FIG 9 show exemplary electric circuitries for the luminance motion detector **1101**, the chrominance motion detectors **1102/1103**, the smoothness detectors **1104/1105**, and the phase motion detectors **1106/1107** in accordance with one embodiment of the present invention.

[0020] FIG 10 shows an exemplary circuit of the motion detector for PAL standard in accordance with another embodiment of the present invention.

[0021] FIG 11 shows an exemplary circuit of the cross luminance suppression circuit **2001** in the baseband YC separation circuitry **2000** as shown in FIG 4 for PAL standard in accordance with one embodiment of the present invention.

[0022] FIG 12 shows an exemplary circuit of the cross chroma suppression circuits **2002/2003** in the baseband YC separation circuitry **2000** as shown in FIG 4 for PAL standard in accordance with one embodiment of the present invention.

[0023] FIG 13 shows a functional block diagram of a motion detector disclosed in the prior art.

Detailed Description of the Invention

[0024] The present invention may be understood more readily by reference to the following detailed description of certain embodiments of the invention.

[0025] Throughout this application, where publications are referenced, the disclosures of these publications are hereby incorporated by reference, in their entireties, into this application in order to more fully describe the state of art to which this invention pertains.

[0026] While embodiments of the present invention will be described in reference to the accompanying drawings, the specifics and details are provided for the sole purpose of illustrating selected embodiments of the present invention. It is to be appreciated that the present invention may be practiced without employing the specifics and details. Furthermore, certain variations of the specifics and details in the practice are permissible without deviation from the scope of the appended claims.

[0027] In one embodiment of the present invention, there is provided a motion detection system that detects all types of motions including high frequency luminance motion and chroma motion independent of the signal processing done prior to input. Briefly, the motion detection system comprises a luminance motion detector detecting the low frequency luminance changes; a chrominance motion detector detecting the chroma changes; a smoothness detector detecting the flat regions in chroma component; and a phase motion detector detecting the high frequency luminance and chroma changes.

[0028] Now referring to FIG 1, there is provided a functional block diagram of the circuitry of the motion detection system for the NTSC standard in accordance with one embodiment of the present invention. The motion detection system **100** comprises a luminance motion detector **101** that detects low frequency luminance motion between frame n and $n-1$; chrominance motion detectors **102/103** that detect U and V chroma motion between frame n and $n-1$ respectively; smoothness detectors **104/105** that detect presence of luminance residue on U and V chroma components in frame n and $n-1$ respectively; phase motion detectors **106** and **107** that detect average luminance and chroma motion between frames n , $n-1$, $n-2$ and $n-3$; and chroma motion combiner **108** that integrates the motions derived from U and V components. The motion detection system **100** further comprise a Max **606**, a saturation circuit **607**, and a 5H-max circuit **608**, which functions will be described in detail hereinafter. The saturation circuits clip an input signal to a defined output range, and the 5H-max circuit chooses the maximum value of 5 consecutive pixels in a horizontal window.

[0029] With reference to FIG 2, there are provided exemplary electric circuitries for the luminance motion detector **101**, the chrominance motion detectors **102/103**, the smoothness detectors **104/105**, and the phase motion detectors **106/107** in accordance with one embodiment of the present invention.

[0030] The luminance motion detector **101** detects precisely changes in the luminance component between frame n and frame $n-1$ used for the frame comb in NTSC standard. The input signal is vertically filtered to remove chroma residue, to present the best-case line-comb Y signal for difference computation. The output signal is low-pass filtered to eliminate the possibility of chroma component corruption at high frequency.

[0031] The luminance motion detector **101** receives three line signals from each of the current frame n and the previous frame $n-1$. For the current frame n , the three line signals are the next line signal $Y_{m+1,n}$, current line signal $Y_{m,n}$, previous line signal $Y_{m-1,n}$ via two luminance line delay memories, where m denotes the line number. A vertical low pass filter **201** with coefficients $[1\ 2\ 1]/4$ is used to cancel out-of-phase chroma signal to generate line-comb signal YLC_n . Concurrently, the luminance motion detector **101** also receives three line signals from the previous frame $n-1$: next line signal $Y_{m+1,n-1}$, current line signal $Y_{m,n-1}$ and previous line signal $Y_{m-1,n-1}$, via one luminance frame delay memory and two additional luminance line delay memories. Similarly, a vertical low pass filter **202** is used to generate line-comb signal YLC_{n-1} . The line-comb signals YLC_n and YLC_{n-1} may alternatively be the output of line combs of the baseband circuitry.

[0032] These line-comb signals YLC_n and YLC_{n-1} are then subtracted by a subtractor **203**. A horizontal low pass filter **204**, with low pass frequency characteristics not exceeding the lower end of the overlapping frequency band of chroma and luminance signal or band-stop frequency characteristics covering the chroma band, subsequently filters the line-comb signal differences to exclude possible interference of chroma residue. The magnitude is extracted by an absolute circuit **205** and passed through a coring circuit **206** to eliminate possible noise interference. Finally, the magnitude is multiplied by a multiplier **207** with gain, $YGain (GI)$, and clipped by a saturation circuit **208** to appropriate motion range to generate low frequency luminance motion YLn .

[0033] The chroma motion detectors **102/103** detect precisely changes in the chroma components between frame n and frame $n-1$ used for frame comb in NTSC standard. The input signal is vertically filtered to remove luminance residue, to present

best case line-comb C signal for difference computation. While each chroma component U or V is processed independently by the chrominance motion detectors **102/103** to generate chroma motions UD and VD , the operations for each chroma component are the same; thus for the sake of convenience, CD is used to refer inter-changeably to either UD or VD in this document.

[0034] Similar to the luminance motion detector **101**, the chrominance motion detector **102/103** receives three line signals from each of the current frame n and previous frame $n-1$. For the current frame n , the three line signals are next line signal $C_{m+1,n}$, current line signal $C_{m,n}$, previous line signal $C_{m-1,n}$ via 2 chroma line delay memories. A vertical low pass filter **301** with coefficients $[1 \ 2 \ 1]/4$ is used to cancel out-of-phase luminance signal to generate line-comb signal, CLC_n . Concurrently, the chrominance motion detector **102/103** receives three line signals from the previous frame $n-1$: next line signal $C_{m+1,n-1}$, current line signal $C_{m,n-1}$, and previous line signal $C_{m-1,n-1}$, received via one chroma frame delay memory and two chroma line delay memories. The line signals are vertically filtered by a vertical low pass filter **302** to generate line-comb signal, CLC_{n-1} . The signals CLC_n and CLC_{n-1} may be the output of line combs in a baseband circuitry discussed in detail hereinafter.

[0035] These line-comb signals CLC_n and CLC_{n-1} are then subtracted by a subtractor **303**. Its magnitude is extracted by an absolute circuit **304** to generate intermediate chroma motion CD_p , low pass filtered by a horizontal low pass filter **305** to smoothen transitions, and passed through a coring circuit **306** to eliminate possible noise interference. Finally, the magnitude is multiplied by a multiplier **307** with gain, $CGAIN$ ($G2$), and clipped by a saturation circuit **308** to appropriate motion range to generate chroma motion CD .

[0036] The smoothness detector **104/105** detects the presence of luminance residue in chroma components. The detector uses a constructive phase-subtraction diagonally within field and temporally between frame n and frame $n-1$ used for frame comb in NTSC standard. A null output indicates flat region and accuracy of the chroma motion detector **102/103**. While each chroma component U or V is processed independently by smoothness detector to generate high frequency signal UF and VF , the operations for each chroma component are the same; thus for the sake of convenience, CF shall refer inter-changeably to either UF or VF in this document.

[0037] As the chroma motion may be influenced by luminance residue in chroma signal, it is desirable to differentiate between true and false chroma motion. The smoothness detectors **104/105** detect the presence of luminance residue and invalidate or override the output of respective chrominance motion detectors. The smoothness detectors **104/105** receive the same input as the chrominance motion detector **102/103**: next line signal $C_{m+1,n}$, current line signal $C_{m,n}$, and previous line signal $C_{m-1,n}$ for current frame n ; next line signal $C_{m+1,n-1}$, current line signal $C_{m,n-1}$, and previous line signal $C_{m-1,n-1}$ for previous frame $n-1$.

[0038] The smoothness detectors **104/105** include both forward and backward diagonal contributions. The line signals of current and previous frames are diagonally filtered by forward diagonal high pass filters **401/402**, and backward diagonal high pass filters **403/404** with common coefficients $[-1 \ 2 \ -1]/4$. The input vector for forward diagonal contribution is $[C_{x-1,m+1} \ C_{x,m} \ C_{x+1,m-1}]$ while the input vector for backward diagonal contribution is $[C_{x-1,m-1} \ C_{x,m} \ C_{x+1,m+1}]$ where x is the horizontal position of the pixel. The forward diagonally filtered signals are subtracted by a subtractor **405** and its magnitude is extracted by an absolute circuit **407**. The backward diagonally filtered signals are subtracted by a subtractor **406** and its magnitude is extracted by an absolute circuit **408**. A max circuit **409** selects the maximum of the forward or backward contribution to generate an intermediate high frequency signal CF_p . The CF_p is filtered by a horizontal low pass filter **410** to smooth transitions and then cored by a coring circuit **411** to eliminate small noise. A gain $SmoGain$ ($G3$) via a multiplier **412** is multiplied to the filtered output, and the signal is clipped by a saturation circuit **413** to generate high frequency signal CF . Alternatively, circuits **410-413** may be replaced by binary thresholding circuit to output 0 in presence of flat region and 1 in presence of luminance residue.

[0039] The phase motion detectors **106/107** detect the luminance and chroma changes from the temporally co-located pixels in chroma components. The changes are made independent of luminance residue in chroma by considering the phase relationship of the interleave signal. Chroma pixels from current frame n (C_n), and three previous frames $n-1$ (C_{n-1}), $n-2$ (C_{n-2}), and $n-3$ (C_{n-3}) in NTSC standard are used to determine motion according to the following equation (1):

[0040]
$$YCD = \text{Max} \left\{ \left| C_n + C_{n-1} - C_{n-2} - C_{n-3} \right|, \left| C_n - C_{n-1} - C_{n-2} + C_{n-3} \right| \right\} \quad (1)$$

[0041] From one perspective, the first component gives the average chroma motion between frame n and $n-2$ while the second component measures the average luminance motion between frame n and $n-2$. From another perspective, the first component gives the difference in luminance motion between frame n and $n-1$ and frame $n-2$ and $n-3$ while the second component gives the difference in chroma motion between frame n and $n-1$ and frame $n-2$ and $n-3$.

[0042] While each chroma component U or V is processed independently by the phase motion detectors **106/107** to generate YC motion signal YUD and YVD , the operations for each chroma component are the same; thus for the sake of convenience, YCD shall refer inter-changeably to either YUD or YVD in this document.

[0043] The phase motion detectors **106/107** detect mainly chroma motion in the presence of luminance residue and high frequency luminance motion. The phase motion detectors **106/107** receive the current frame signal, $C_{m,n}$, and a plurality of previous frame signals $C_{m,n-1}$, $C_{m,n-2}$, and $C_{m,n-3}$, via three chroma frame delay memories. Then the intermediate motion values YCD_p is computed via a circuit **501** according to the equation (2) below:

[0044]

$$YCD_p = \text{Max} \left\{ \left| C_{m,n} + C_{m,n-1} - C_{m,n-2} - C_{m,n-3} \right|, \left| C_{m,n} - C_{m,n-1} - C_{m,n-2} + C_{m,n-3} \right| \right\} \quad (2)$$

[0045] The motion values may be smoothed by a horizontal low pass filter **502** and cored through a coring circuit **503**. It may be scaled by gain PhaseGain ($G4$) via a multiplier **504** and clipped by a saturation circuit **505** to generate YC motion signal, YCD .

[0046] It is obvious to those skilled in the art that the same phase motion detector **106/107** may be applied on the luminance component to generate YC motion values according to the equation (3) below.

$$YCD_p = \text{Max} \left\{ \left| Y_{m,n} + Y_{m,n-1} - Y_{m,n-2} - Y_{m,n-3} \right|, \left| Y_{m,n} - Y_{m,n-1} - Y_{m,n-2} + Y_{m,n-3} \right| \right\} \quad (3)$$

[0047] In this case, the phase motion detector can complement detection of high frequency luminance that may not be present as luminance residue in chroma signal.

[0048] As each of the above detectors has its advantages and limitations, they are combined constructively to give measures of motion between the frames to be filtered.

[0049] Now referring back to FIG 1, the chroma combiner **108** combines results from independent detectors with U or V inputs. In the case of 4:2:2 sampling format, the

samples of independent chroma is half that of luminance. The maximum chroma motion UD and VD is taken and duplicated corresponding to 2 luminance samples by a maxD circuit **601** to give $C2D$. Similarly, the maximum high frequency signal UF and VF is taken and duplicated by a maxD circuit **602** to give $C2F$ and the maximum YC motion YUD and YVD is taken and duplicated by a maxD circuit **603** to give $YC2D$. Thus, the duplicated signals have the same sample rate as luminance motion.

[0050] To suppress false chroma motion detected from luminance interference or temporally averaged motion, signals $C2D$ and $YC2D$ pass through a max circuit **604**. The output is further modified by a selector **605**. Output from the max circuit **604** is selected when flat chroma region is detected or $C2F = 0$ and signal $YC2D$ is selected in presence of luminance residue or $C2F \neq 0$ to give signal CM . This compensates for undetected chroma motion by phase motion detector due to averaging effect in phase motion detector.

[0051] The final motion value, K_motion , is derived as the maximum **606** between the motion detected from luminance YM and motion detected from chrominance CM , clipped by a saturation circuit **607**, and further processed as the maximum in a 5-pixel horizontal window by 5H-max circuit **608**.

[0052] Referring to FIG 3, there is provided an exemplary circuitry of the motion detection system for NTSC standard in accordance with another embodiment of the present invention. Instead of combining the outputs of U and V detectors in the chroma combiner **108** as shown in FIG 1, the intermediate output signals are combined before the filtering, coring, scaling and saturation processes. Intermediate chroma motions UD_p and VD_p are generated as before and combined either by simply interleaving UV or taking the maximum of UV and duplicating result via a maxD circuit **701**. The intermediate signal, $C2D_p$, is passed through a horizontal low pass filter **702**, coring circuit **703**, scaling circuit **704** and saturation circuit **705** to generate combined chroma motion $C2D$.

[0053] Intermediate chroma high frequency signals UF_p and VF_p are generated via plurality of diagonal filters and subsequently combined either by simply interleaving UV or taking the maximum of UV and duplicating result via a maxD circuit **801**. The intermediate signal, $C2F_p$, is passed through a horizontal low pass filter **802**, coring circuit **803**, scaling circuit **804** and saturation circuit **805** to generate combined high frequency signal $C2F$. Alternatively, signal $C2F_p$ may be binary thresholded to output $C2F=0$ in presence of flat region and $C2F=1$ in presence of luminance residue.

[0054] Likewise, intermediate YC motion signals YUD_p and YVD_p are generated through an arithmetic circuit **901** and combined either by UV interleaving or duplicating maxd motion by the circuit **901**. The output signal $YC2D_p$ that is subsequently processed by a horizontal low pass filter **902**, coring circuit **903**, scaling circuit **904** and saturation circuit **905** to generate combined YC motion signal $YC2D$.

[0055] The various signals $C2D$, $C2F$ and $YC2D$ are combined through a selector circuit **1002** that selects $YC2D$ when luminance residue is detected or the maximum of $C2D$ and $YC2D$ via a max circuit **1001** when flat chroma region is detected, according to control signal $C2F$.

[0056] Referring to FIG 4, there is provided a functional block diagram showing a baseband YC separation circuitry in accordance with one embodiment of the present invention. As shown in FIG 4, the baseband YC separation circuitry **2000** comprises a cross luminance suppression circuit **2001** that suppresses dot crawl artifacts or chroma residue present in Y signal, a cross chroma (U) suppression circuit **2002** that suppresses cross colour artifacts or luminance residue present in U signals, a cross chroma (V) suppression circuit **2003** that suppresses cross colour artifacts or luminance residue present in V signals, and a baseband motion detector **2004** that differentiate between the moving and the stationary pixels such that the optimum comb filter can be selected to maximize effectiveness of YC separation. The baseband YC separation circuitry **2000** receives Y_{in} , U_{in} and V_{in} input signals separately and outputs the clean Y_{out} , U_{out} and V_{out} signals. The operation of such a baseband motion detector **2004** has been described above.

[0057] Referring to FIG 5, there is provided an exemplary circuit of the cross luminance suppression circuit **2001** for the NTSC standard in accordance with one embodiment of the present invention. A wideband filter **2101** with frequency response modeling the chroma band in composite signal and complementary to the horizontal filter **204** shown in FIG 1 filters out the low and high frequency signal and retains only the frequency band with interleave Y and C signal. The line comb **2102** removes the redundant chroma residue from the Y signal. It has a 3 line input, next line $Y_{m+1,n,wbp}$, current line $Y_{m,n,wbp}$ and previous line $Y_{m-1,n,wbp}$. The inter-line differences are computed by subtractors **2103** and **2104** and subsequently mixed by a mixer **2105** corresponding to K_2D signal from the inter-line correlator **2106** described hereinafter.

[0058] The inter-line correlator **2106** detects the relative chroma correlation between the current and next line and current and previous line, such that the line comb does not filter across contrasting colour regions. The Y signal passes through the narrowband filter **2107** to isolate the sub-band of the YC interleave frequency band. The narrowband filter has a smaller bandwidth centered at chroma subcarrier frequency of 3.58MHz compared to the wideband filter for purposes of less interference from luminance signal. The gradients of current and next line, $G_{x,m,m+1}$, and current and previous line, $G_{x,m,m-1}$, are computed in gradient circuits **2108** and **2109** using band-passed Y signal represented by Y for simplicity according to the following equations (4-5) or (6-7).

[0059]

$$\begin{aligned} G_{x,m,m+1} &= \min \left\{ \max \left\{ |Y_{x,m+1} - Y_{x+2,m}|, |Y_{x+2,m+1} - Y_{x,m}| \right\}, \max \left\{ |Y_{x,m+1} - Y_{x-2,m}|, |Y_{x-2,m+1} - Y_{x,m}| \right\} \right\} \\ G_{x,m,m-1} &= \min \left\{ \max \left\{ |Y_{x,m-1} - Y_{x+2,m}|, |Y_{x+2,m-1} - Y_{x,m}| \right\}, \max \left\{ |Y_{x,m-1} - Y_{x-2,m}|, |Y_{x-2,m-1} - Y_{x,m}| \right\} \right\} \end{aligned} \quad (4)$$

[0060]

$$G_{x,m,m+1} = \max \left\{ |Y_{x+1,m+1} - Y_{x-1,m}|, |Y_{x-1,m+1} - Y_{x+1,m}| \right\} \quad (6)$$

$$G_{x,m,m-1} = \max \left\{ |Y_{x+1,m-1} - Y_{x-1,m}|, |Y_{x-1,m-1} - Y_{x+1,m}| \right\} \quad (7)$$

[0061] They are subsequently filtered by horizontal low pass filters **2110** and **2111** for continuity. The lower the gradient, the higher the correlation, meaning a higher possibility that the pixels from the two lines belong to the same colour region. Thus line-comb output from two lines having a lower gradient should have a higher contribution towards the final comb value. K_2D is defined as the weight for the line comb filter between the current and previous line in the function circuit **2112**. K_2D is represented by the equation (8) below.

[0062]

$$K_2D = \frac{G'_{m,m+1}}{G'_{m,m+1} + G'_{m,m-1}} \quad (8)$$

[0063] Alternatively, K_2D can be obtained from the K_2D values generated by the cross chroma suppression circuits **2002** and **2003**. An example method of combining may be represented by the equation (9) below:

$$K_2D = \frac{GU'_{m,m+1} + GV'_{m,m+1}}{GU'_{m,m+1} + GV'_{m,m+1} + GU'_{m,m-1} + GV'_{m,m-1}} \quad (9)$$

[0065] where $GU'_{m,m+1}$ represents the low pass filtered gradient between the current and next line for chroma signal U, $GV'_{m,m+1}$ represents the low pass filtered gradient between the current and next line for chroma signal V, $GU'_{m,m-1}$ represents the low pass filtered gradient between the current and previous line for chroma signal U, and $GV'_{m,m-1}$ represents the low pass filtered gradient between the current and previous line for chroma signal V.

[0066] The output of the line comb filter can be expressed according to the equation (10) below:

$$\mathbf{[0067] \quad } Y_2D = K_2D \times (Y_m - Y_{m-1}) + (1 - K_2D) \times (Y_m - Y_{m+1}); \quad (10)$$

[0068] The frame comb subtracts the previous frame signal $Y_{m,n-1}$ from the current frame signal $Y_{m,n}$ using subtractor **2113** to generate frame comb output Y_3D .

[0069] The residual chroma signal is extracted via a mixer circuit **2114** using motion value, K_motion from the baseband motion detector **2004** and the final clean luminance signal, Y_{out} , is generated according to the equation (11) below by subtracting the residual chroma signal from input luminance signal, Y_m , with a subtractor **2115** and clipping the output to defined pixel range with a saturation circuit **2116**.

$$\mathbf{[0070] \quad } Y_{out} = Y_m - (K_motion \times Y_2D + (1 - K_motion) \times Y_3D) \quad (11)$$

[0071] Referring to FIG 6, there is provided an exemplary circuitry of the cross chroma suppression circuits **2002/2003** in accordance with one embodiment of the present invention. The architecture of the cross chroma suppression circuit is almost similar to the cross luminance suppression circuit. The differences are the absence of the wideband filter for line comb and narrowband filter for inter-line correlator.

[0072] The chroma line comb **2202** removes the redundant luminance residue from the U_{in} or V_{in} signal. Signal C shall be referring to either signal U or V for the cross chroma suppression circuit. It has a three line input, next line $C_{m+1,n,wbp}$, current line $C_{m,n,wbp}$ and previous line $C_{m-1,n,wbp}$. The inter-line differences are computed by subtractors **2203** and **2204** and subsequently mixed by a mixer **2205** corresponding to K_2D signal from the inter-line correlator **2206**.

[0073] The inter-line correlator **2206** detects the relative chroma correlation between the current and next line and current and previous line, such that the chroma line comb does not filter across contrasting colour regions. A low pass filter can be applied

prior to gradient computation to exclude influence of luminance on chroma signal. The gradients of current and next line, $G_{x,m,m+1}$, and current and previous line, $G_{x,m,m-1}$, are computed in gradient circuits **2208** and **2209** according to the equations (12) and (13) below.

[0074]

$$\begin{aligned} G_{x,m,m+1} &= \min\left\{\max\left\{|C_{x,m+1} - C_{x+1,m}|, |C_{x+1,m+1} - C_{x,m}|\right\}, \max\left\{|C_{x,m+1} - C_{x-1,m}|, |C_{x-1,m+1} - C_{x,m}|\right\}\right\}, \\ G_{x,m,m-1} &= \min\left\{\max\left\{|C_{x,m-1} - C_{x+1,m}|, |C_{x+1,m-1} - C_{x,m}|\right\}, \max\left\{|C_{x,m-1} - C_{x-1,m}|, |C_{x-1,m-1} - C_{x,m}|\right\}\right\} \end{aligned} \quad (12)$$

[0075] They are subsequently filtered by horizontal low pass filters **2210** and **2211**. (13)

The lower the gradient, the higher the correlation, meaning a higher possibility that the pixels from the two lines belong to the same colour region. Thus line-comb output from two lines having a lower gradient should have a higher contribution towards the final comb value. K_2D is defined as the weight for the line comb filter between the current and previous chroma line in the function circuit **2212**. K_2D is represented by the equation (14) below.

$$[0076] \quad K_2D = \frac{G'_{m,m+1}}{G'_{m,m+1} + G'_{m,m-1}} \quad (14)$$

[0077] K_2D from the cross chroma suppression circuits **2002** and **2003** can be combined using a max function and upsampled by 2 or interleaved to provide the K_2D for the cross luminance suppression circuit **2001**.

[0078] The output of the line comb filter can be expressed by the equation (15) below.

$$[0079] \quad C_2D = K_2D \times (C_m + C_{m-1}) + (1 - K_2D) \times (C_m + C_{m+1}); \quad (15)$$

[0080] The frame comb adds the previous frame signal $C_{m,n-1}$ from the current frame signal $C_{m,n}$ using an adder **2213** to generate frame comb output C_3D .

[0081] The final 3D value, C_{out} , is generated via a mixer circuit **2214** using motion value, K_motion from the baseband motion detector **2004** and clipped to valid pixel range with a saturation circuit **2216**. C_{out} can be represented by the equation (16) below.

$$[0082] \quad C_{out} = K_motion \times C_2D + (1 - K_motion) \times C_3D \quad (16)$$

[0083] Referring to FIG 7, there is provided a functional block diagram of a video signal processing system in accordance with one embodiment of the present invention. The signal processing system **4000** comprises a front end digital decoder **4001** and a

baseband YC separation module **4007**. The front end digital decoder **4001** decodes the composite input signals to generate component Y, U and V signals. The decoder **4001** comprises a synchronization unit **4002** to capture the video synchronization signals and to lock the system clock to the frequency and phase of the incoming signal using the chroma burst, an input sample rate convertor **4003** to re-sample the acquisition sample rate of 27MHz to four times the sub-carrier frequency, a YC separation circuit **4004** to separate chroma and luminance signal from the composite signal, a chroma demodulator **4005** to demodulate the chroma signal according chroma phase lock loop, an output sample rate convertor and scaler **4006** to re-sample the separated signals to output sampling rate domain and to scale the video signal to required dynamics.

[0084] The component signals from the decoder **4001** are input to the baseband YC separation circuit **4007** for further 3D comb filtering. The baseband YC separation circuit **4007** as described above is a second separation circuit in the signal processing system to compensate for inefficiency of the first separation circuit **4004** and to eliminate residual cross component signals. As such, the operation of the first separation circuit **4004** in composite domain may be simplified. In one embodiment, the baseband YC separation circuit **4007** may be a 3D comb filter using a mix of frame comb and line comb controlled by a motion detector. In another embodiment, the baseband YC separation circuit **4007** may be a 2D comb filter with a 3-line comb controlled by an inter-line correlator. In another embodiment, the baseband YC separation circuit **4007** may be a set of complementary or non-complementary filters around the chroma subcarrier frequency with band-stop or notch filter for the Y output and band-pass filter for the C output. In yet another embodiment, the input is bypassed for the Y output and band-pass filtered for the C output. The baseband YC separation circuit must operate independent of the front-end separation circuitry and the motion detector must perform precise motion detection regardless of source input.

[0085] Now there is provided a detailed description of the motion detection system and baseband YC separation circuitry and signal processing system for PAL standard.

[0086] Referring to FIG 8, there is provided a functional block diagram of the circuitry of the motion detection system for the PAL standard in accordance with one embodiment of the present invention. As shown in FIG 8, the motion detection system **1100** comprises a luminance motion detector **1101** that detects low frequency luminance

motion between frames n and $n-2$; chrominance motion detectors **1102** and **1103** that detect U and V chroma motion between frames n and $n-2$; smoothness detectors **1104** and **1105** that detect presence of luminance residue on U and V chroma components in frames n and $n-2$; phase motion detectors **1106** and **1107** that detect average luminance and chroma motion between frames n , $n-2$, $n-3$, $n-4$ and $n-5$; and a chroma motion combiner **1108** that integrates the motion derived from U and V components. The motion detection system **1100** further comprises a max circuit **1606**, a saturation circuit **1607**, and a 5H-max circuit **1608**, which functions will be described hereinafter.

[0087] The motion detector system **1100** for the PAL standard has a similar architecture of the motion detector system **100** for the NTSC standard. But the motion detector system **1100** uses previous frame $n-2$ instead of $n-1$, previous line signals $Y_{m-2,n}$, $C_{m-2,n}$ instead of $Y_{m-1,n}$, $C_{m-1,n}$ and next line signals $Y_{m+2,n}$, $C_{m+2,n}$ instead of $Y_{m+1,n}$, $C_{m+1,n}$ for luminance motion detector, chrominance motion detectors and smoothness detectors and computation specific to phase relationships of the standard in phase motion detector.

[0088] Referring FIG 9, there are provided exemplary electric circuitries for the luminance motion detector **1101**, the chrominance motion detectors **1102/1103**, the smoothness detectors **1104/1105**, and the phase motion detectors **1106/1107** in accordance with one embodiment of the present invention.

[0089] The luminance motion detector **1101** receives three line signals from each of the current frame n and previous frame $n-2$. For the current frame n , the three line signals include the next line signal $Y_{m+2,n}$, current line signal $Y_{m,n}$, previous line signal $Y_{m-2,n}$ via 4 luminance line delay memories. A vertical low pass filtering **1201** with coefficients $[1\ 2\ 1]/4$ is performed to cancel out-of-phase chroma signal to generate line-comb signal YLC_n . Concurrently, for the previous frame $n-2$, the three line signals include the next line signal $Y_{m+2,n-2}$, current line signal $Y_{m,n-2}$ and previous line signal $Y_{m-2,n-2}$, via two luminance frame delay memories and four additional luminance line delay memories. Similarly, a vertical low pass filtering **1202** is performed to generate line-comb signal YLC_{n-2} . The line-comb signals YLC_n and YLC_{n-2} may alternatively be the output of line combs of the baseband circuitry.

[0090] These line-comb signals YLC_n and YLC_{n-2} are then subtracted by a subtractor **1203**. The horizontal low pass filter **1204**, with low pass frequency characteristics not exceeding the lower end of the overlapping frequency band of chroma

and luminance signal or band-stop frequency characteristics covering the chroma band, subsequently filters the line-comb signal differences to exclude possible interference of chroma residue. The magnitude is extracted by an absolute circuit **1205** and passed through a coring circuit **1206** to eliminate possible noise interference. Finally, it is multiplied by gain, $YGain (G1)$ via a multiplier **1207**, and clipped by a saturation circuit **1208** to appropriate motion range to generate low frequency luminance motion YM .

[0091] Similar to the luminance motion detector **1101**, the chrominance motion detector **1102/1103** receives three line signals from each of the current frame n and previous frame $n-2$. For the current frame n , the three line signals include the next line signal $C_{m+2,n}$, current line signal $C_{m,n}$, previous line signal $C_{m-2,n}$ via four chroma line delay memories. A vertical low pass filter **1301** with coefficients $[1\ 2\ 1]/4$ is used to cancel out-of-phase luminance signal to generate line-comb signal, CLC_n . Concurrently, for the previous frame $n-2$, the three line signals include the next line signal $C_{m+2,n-2}$, current line signal $C_{m,n-2}$, previous line signal $C_{m-2,n-2}$, received via two chroma frame delay memories and four chroma line delay memories, which are vertically filtered by a vertical low pass filter **1302** to generate line-comb signal CLC_{n-2} . The signals CLC_n and CLC_{n-2} may be from the output of line combs in a baseband circuitry described in detail hereinafter.

[0092] These line-comb signals CLC_n and CLC_{n-2} are then subtracted by a subtractor **1303**. Its magnitude is extracted by an absolute circuit **1304** to generate intermediate chroma motion CD_p and low pass filtered by a horizontal low pass filter **1305** to smoothen transitions and passed through a coring circuit **1306** to eliminate possible noise interference. Finally, it is multiplied by gain, $CGAIN (G2)$ via a multiplier **1307**, and clipped by a saturation circuit **1308** to appropriate motion range to generate chroma motion CD .

[0093] The smoothness detectors **1104** and **1105** detect the presence of luminance residue and invalidate or override the output of respective chrominance motion detectors. The smoothness detectors **1104/1105** include both forward and backward diagonal contributions. The line signals of current and previous frames are diagonally filtered by forward diagonal high pass filters **1401/1402**, and backward diagonal high pass filters **1403/1404** with common coefficients $[-1\ 2\ -1]/4$. It receives the same input as the chrominance motion detector with three line signals from the current frame n : next line signal $C_{m+2,n}$, current line signal $C_{m,n}$, previous line signal $C_{m-2,n}$ and three line signals from

the previous frame $n-2$: next line signal $C_{m+2,n-2}$, current line signal $C_{m,n-2}$, previous line signal $C_{m-1,n-2}$.

[0094] The line signals of current and previous frames are diagonally filtered by forward diagonal high pass filters **1401** and **1402**, and backward diagonal high pass filters **1403** and **1404** with common coefficients $[-1 \ 2 \ -1]/4$. The input vector for forward diagonal contribution is $[C_{x-1,m+2} \ C_{x,m} \ C_{x+1,m-2}]$ while the input vector for backward diagonal contribution is $[C_{x-1,m-2} \ C_{x,m} \ C_{x+1,m+2}]$. The forward diagonally filtered signals are subtracted by a subtractor **1405** and its magnitude is extracted by an absolute circuit **1407**. The backward diagonally filtered signals are subtracted by a subtractor **1406** and its magnitude is extracted by an absolute circuit **1408**. The max circuit **1409** selects the maximum of the forward or backward contribution to generate intermediate high frequency signal CF_p . The signal is filtered by a horizontal low pass filter **1410** to smooth transitions and then cored by a coring circuit **1411** to eliminate small noise. A gain $SmoGain$ ($G3$) **1412** is multiplied to the filtered output and signal is then clipped by a saturation circuit **1413** to generate high frequency signal CF . Alternatively, circuits **1410-1413** may be replaced by binary thresholding circuit to output 0 in presence of flat region and 1 in presence of luminance residue.

[0095] The phase motion detectors **1106/1107** complement the above detectors by detecting mainly chroma motion in the presence of luminance residue and high frequency luminance motion. Each receives the current frame signal, $C_{m,n}$, and a plurality of previous frame signals $C_{m,n-1}$, $C_{m,n-2}$, $C_{m,n-3}$ and $C_{m,n-4}$, via four chroma frame delay memories. Then each computes intermediate motion values YCD_p via a circuit **1501** according to the equation (17) below.

[0096]

$$YCD_p = \text{Max} \left\{ \left| C_{m,n} - C_{m,n-1} + C_{m,n-2} - C_{m,n-3} \right|, \left| C_{m,n-1} - C_{m,n-2} + C_{m,n-3} - C_{m,n-4} \right| \right\} \quad (17)$$

[0097] The first component detects average chroma and luminance motion for plurality of frames from n to $n-3$ while the second component detects average chroma and luminance motion for plurality of frames from $n-1$ to $n-4$. As each component is asymmetrical about the temporal center, any scene change or chroma motion only occurring between second and third frame is not detected. Thus, a second component guarantees full motion detection.

[0098] The motion values may be smoothed by a horizontal low pass filter **1502** and cored through a coring circuit **1503**. It may be scaled by gain PhaseGain (G4) via a multiplier **1504** and clipped by a saturation circuit **1505** to generate YC motion signal, *YCD*.

[0099] The same phase motion detectors **1106/1107** may be applied on the luminance component to generate YC motion values according to the equation (18) below.

[00100]

$$YCD_p = \text{Max} \left\{ \left| Y_{m,n} - Y_{m,n-1} + Y_{m,n-2} - Y_{m,n-3} \right|, \left| Y_{m,n-1} - Y_{m,n-2} + Y_{m,n-3} - Y_{m,n-4} \right| \right\} \quad (18)$$

[00101] In this case, the phase motion detector can complement detection of high frequency luminance that may not be present as luminance residue in chroma signal.

[00102] The chroma combiner **1108** combines results from independent detectors with U or V inputs. In the case of 4:2:2 sampling format, the samples of independent chroma is half that of luminance. The maximum chroma motion *UD* and *VD* is taken and duplicated corresponding to two luminance samples by a maxD circuit **1601** to give *C2D*. Similarly, the maximum high frequency signal *UF* and *VF* is taken and duplicated by a maxD circuit **1602** to give *C2F* and the maximum YC motion *YUD* and *YVD* is taken and duplicated by a maxD circuit **1603** to give *YC2D*. The duplicated signals have the same sample rate as luminance motion.

[00103] Signals *C2D* and *YC2D* pass through the max circuit **1604** and is further modified by the selector **1605**. Output from max circuit 1604 is selected when a flat chroma region is detected or *C2F* = 0 and signal *YC2D* is selected in presence of luminance residue or *C2F* ≠ 0 to give signal *CM*. This compensates for undetected chroma motion by phase motion detector due to averaging effect in phase motion detector.

[00104] The final motion value, *K_motion*, is derived as the maximum **1606** between the motion detected from luminance *YM* and motion detected from chrominance *CM*, clipped by the saturation circuit **1607**, and further processed as the maximum in a 5-pixel horizontal window by the 5H-max circuit **1608**.

[00105] Referring to FIG 10, there is provided an exemplary circuit of the motion detector for PAL standard in accordance with another embodiment of the present invention. Instead of combining the outputs of U and V detectors in the chroma combiner **1108**, the intermediate output signals are combined before the filtering, coring, scaling and

saturation processes. The detailed description is similar to the one for NTSC standard described above.

[00106] Referring to FIGS 11 and 12, there are provided exemplary circuitries of the cross luminance suppression circuit **2001** and cross chroma suppression circuits **2002/2003** in the baseband YC separation circuitry **2000** as shown in FIG 4 for PAL standard in accordance with one embodiment of the present invention. The technical differences between circuits for the PAL and NTSC lie in the use of next line signal $m+2$ instead of $m+1$ and previous line signal $m-2$ instead of $m-1$ for line comb and previous frame signal $n-2$ instead of $n-1$ and in the design of wideband and narrow band filters for chroma subcarrier at 4.43 MHz instead of 3.58 MHz. Since the operation of the circuitry remains the same, detailed description of cross luminance suppression circuit **2001** and cross chroma suppression circuits **2002** and **2003** for the PAL standard is not provided.

[00107] Generally, the invention is embedded in a baseband YC separation circuitry that reduces chroma residue in luminance component and luminance residue in chroma component. A preferred embodiment of the baseband YC separation circuitry comprises of a line comb filter that performs vertical filtering and a frame comb filter that performs temporal filtering. The invention is applied as a baseband motion detector to detect the motion between the candidate frames for temporal filtering. A mixer selects a high weight on the frame comb when the pixels are detected as stationary or selects a high weight on the line comb when pixels are detected as moving.

[00108] The inputs to the baseband circuitry may be processed by a front end digital decoder. In this case, the front end digital decoder receives the composite signal or s-video signal and decodes it into component Y, U and V signals for processing in baseband. The decoding process may include YC separation with a simple 2D comb filter for example a line comb, a 3D comb filter for example a line and frame comb controlled by a motion detector, a notch filter for the Y signal and bandpass filter for the C signal, or simply a demodulation circuitry.

[00109] Alternatively, the inputs may be processed by video decoder for example an MPEG 2 decoder. The inputs to the baseband motion detector may or may not be pre-processed by the baseband YC separation circuitry. Thus the invention is expected to consider the same variety of inputs as the baseband YC separation circuitry.

[00110] The invention operates such that the inputs are not temporally filtered in the presence of motion and temporally filtered in the absence of motion, generating clean Y, U and V signals with reduction of cross colour and dot crawl and ensuring minimally modified signals in the absence of such artifacts.

[00111] It can be applied to a chip or end consumer products like television, display sets, video CD player, DVD players or recorders and set-top-boxes with composite sources or sources that have composite conversion in at least one stage of processing prior to input.

[00112] While the present invention has been described with reference to particular embodiments, it will be understood that the embodiments are illustrative and that the scopes of the appended claims are not so limited. Alternative embodiments of the present invention have been set forth by implication and will be apparent to those having ordinary skill in the art to which the present invention pertains. Such alternate embodiments are considered to be encompassed within the scope of one or more of the appended claims. Accordingly, the scope of the present invention is described by the appended claims and is supported by the foregoing description.

CLAIMS

What is claimed is:

1. A motion detection system for video signal processing, comprising:
 - a luminance motion detector for detecting the low frequency luminance motion between a current frame and a previous frame;
 - at least two chrominance motion detector for detecting U and V chroma motions between a current frame and a previous frame;
 - a smoothness detector for detecting presence of luminance residue on U and V chroma components in a current frame and a previous frame; and
 - a phase motion detector for detecting luminance and chroma motion between a current frame and a plurality of previous frames;thereby the motion detection system detects all types of motions in the current frame of the video signal so that it can improve the baseband YC separation for the video signal processing.
2. The motion detection system of claim 1, further comprising:
 - a chroma motion combiner for integrating the motions derived from U and V components, said chroma motion combiner for NTSC standard comprising a Maxd circuit for processing the signals from each of the chrominance motion detector, the smoothness detector, and the phase motion detector, a max circuit coupled to the Maxd circuits for suppressing false chroma motion detected, and a selector for modifying the motion detected; or said chroma motion combiner for PAL standard comprising a max circuit coupled to the each of the chrominance motion detector, the smoothness detector, and the phase motion detector for suppressing false chroma motion detected, and a selector for modifying the motion detected.
3. The motion detection system of claim 2, further comprising
 - a max circuit coupled to the luminance motion detector and chroma motion combiner for selecting the maximum between the motion detected from luminance *YM* and motion detected from chrominance *CM*;

a saturation circuit coupled to the max circuit for clipping the maximum; and
 a 5H-max circuit coupled to the saturation circuit for processing the maximum in a 5-pixel horizontal window to derive the final motion value, K_{motion} .

4. The motion detection system of claim 1, wherein the luminance motion detector comprises:

at least two vertical low pass filters for low pass filtering at least three line luminance signals of the current frame and previous frame received from an input means, outputting line comb signals;

a subtractor coupled to the at least two vertical low pass filters to subtract the line comb signals;

a horizontal low pass filter coupled to the subtractor for subsequently low pass filtering the line-comb signal differences to exclude possible interference of chroma residue;

an absolute circuit coupled to the horizontal low pass filter for extracting the magnitude of the line-comb signals;

a coring circuit coupled to the absolute circuit for eliminating possible noise interference the magnitude;

a multiplier coupled to the coring circuit for multiplying the magnitude by a gain; and

a saturation circuit coupled to the multiplier for clipping an appropriate motion range of the magnitude to generate low frequency luminance motion Y_{Mn} .

5. The motion detection system of claim 4, wherein the at least two vertical low pass filters have low pass frequency characteristics not exceeding the lower end of the overlapping frequency band of chroma and luminance signal or band-stop frequency characteristics covering the chroma band.

6. The motion detection system of claim 4, wherein the current frame and previous frame are frame n and frame $n-1$ respectively for NTSC standard or are frame n and frame $n-2$ respectively for PAL standard.

7. The motion detection system of claim 1, wherein each of the at least two chroma motion detectors comprises:

at least two vertical low pass filters for low pass filtering at least three line chroma signals of the current frame and previous frame received from an input means, outputting line comb chroma signals;

a subtractor coupled to the at least two chroma motion detectors for subtracting the line comb chroma signals;

an absolute circuit coupled to the subtractor for extracting the magnitude of the line comb chroma signals to generate an intermediate chroma motion CD_p ;

a horizontal low pass filter coupled to the absolute circuit for low pass filtering the line comb chroma signals to smoothen transitions;

a coring circuit coupled to the horizontal low pass filter for eliminating possible noise interference of the magnitude;

a multiplier coupled to the coring circuit for multiplying the magnitude with a gain; and

a saturation circuit coupled to the multiplier for clipping the magnitude to an appropriate motion range to generate chroma motion CD .

8. The motion detection system of claim 7, wherein each of the at least two chroma motion detectors further optionally comprises a Maxd circuit between the absolute circuit and the horizontal low pass filter for taking and duplicating the maximum.

9. The motion detection system of claim 7, wherein the current frame and previous frame are frame n and frame $n-1$ respectively for NTSC standard or are frame n and frame $n-2$ respectively for PAL standard.

10. The motion detection system of claim 1, wherein each of the at least two smoothness detectors comprises:

at least two forward diagonal high pass filters for diagonally filtering three line chroma signals of the current frame and previous frame received from an inputting means;

at least two backward diagonal high pass filters for diagonally filtering three line chroma signals of frames n and $n-1$ received from an inputting means;

at least two subtractors coupled to the high pass filters for subtracting the filtered signals;

at least two absolute circuits coupled to the at least two subtractors for extracting the magnitude of the filtered signals;

a max circuit coupled to the at least two absolute circuits for selecting the maximum of the forward or backward contribution to generate an intermediate high frequency signal CF_P ;

a horizontal low pass filter coupled to the max circuit for low pass filtering the intermediate high frequency signal to smooth transitions;

a coring circuit coupled to the horizontal low pass filter for coring the intermediate high frequency signals to eliminate small noise;

a multiplier coupled to the coring circuit for multiplying the filtered output with a gain; and

a saturation circuit coupled to the multiplier for clipping the signal to generate high frequency signal CF .

11. The motion detection system of claim 10, wherein each of the at least two smoothness detectors further optionally comprises a Maxd circuit between the max circuit and the horizontal low pass filter for taking and duplicating the maximum.

12. The motion detection system of claim 10, wherein the current frame and previous frame are frame n and frame n-1 respectively for NTSC standard or are frame n and frame n-2 respectively for PAL standard.

13. The motion detection system of claim 1, wherein each of the at least two phase motion detectors comprises:

a computing circuit receiving signals from the current frame and the plurality of previous frames via an inputting means, said computing circuit computing an intermediate motion values YCD_P ;

a horizontal low pass filter coupled to the computing circuit for smoothing the motion values;

a coring circuit coupled to the horizontal low pass filter for coring the motion values;

a multiplier coupled to the coring circuit for multiplying the motion values with a gain; and

a saturation circuit coupled to the multiplier for clipping the motion values to generate YC motion signal, YCD .

14. The motion detection system of claim 13, wherein the current frame and the plurality of previous frames are frame n and frames $n-1$, $n-2$, and $n-3$ respectively for NTSC standard so that the intermediate motion values YCD_P is computed according to the equation below:

$$YCD_P = \text{Max} \left\{ \left| C_{m,n} + C_{m,n-1} - C_{m,n-2} - C_{m,n-3} \right|, \left| C_{m,n} - C_{m,n-1} - C_{m,n-2} + C_{m,n-3} \right| \right\};$$

wherein the current frame and the plurality of previous frames are frame n and frame $n-1$, $n-2$, $n-3$, $n-4$ respectively for PAL standard so that the intermediate motion values YCD_P is computed according to the equation below:

$$YCD_P = \text{Max} \left\{ \left| C_{m,n} - C_{m,n-1} + C_{m,n-2} - C_{m,n-3} \right|, \left| C_{m,n-1} - C_{m,n-2} + C_{m,n-3} - C_{m,n-4} \right| \right\}.$$

15. The motion detection system of claim 13, wherein each of the at least two phase motion detectors further optionally comprises a Maxd circuit between the computing circuit and the horizontal low pass filter for taking and duplicating the maximum.

16. A process for motion detection for video signal processing, said process comprising the following steps of:

detecting the low frequency luminance motion between a current frame and a previous frame;

detecting U and V chroma motions between a current frame and a previous frame;

detecting presence of luminance residue on U and V chroma components in a current frame and a previous frame; and

detecting luminance and chroma motion between a current frame and a plurality of previous frames;

thereby the motion detection system detects all types of motions in the current frame of the video signal so that it can improve the baseband YC separation for the video signal processing.

17. The process of claim 16, further comprising the following steps of:

integrating the motions derived from U and V components by processing the signals from each of the chrominance motion detector, the smoothness detector, and the phase motion detector; suppressing false chroma motion detected; and modifying the motion detected for NTSC standard; or suppressing false chroma motion detected, and a modifying the motion detected from each of the chrominance motion detector, the smoothness detector, and the phase motion detector for PAL standard.

18. The process of claim 17, further comprising the following steps of

selecting the maximum between the motion detected from luminance YM and motion detected from chrominance CM ;

clipping the maximum; and

processing the maximum in a 5-pixel horizontal window to derive the final motion value, K_{motion} .

19. The process of claim 16, wherein the step of detecting the low frequency luminance motion between a current frame and a previous frame comprises:

low pass filtering at least three line luminance signals of the current frame and previous frame received from an input means, outputting line comb signals;

subtracting the line comb signals;

subsequently low pass filtering the line-comb signal differences to exclude possible interference of chroma residue;

extracting the magnitude of the line-comb signals;

eliminating possible noise interference the magnitude;

multiplying the magnitude by a gain; and

clipping an appropriate motion range of the magnitude to generate low frequency luminance motion YM_n .

20. The process of claim 19, wherein the current frame and previous frame are frame n and frame $n-1$ respectively for NTSC standard or are frame n and frame $n-2$ respectively for PAL standard.

21. The process of claim 16, wherein the step of detecting U and V chroma motions between a current frame and a previous frame comprises:

low pass filtering at least three line chroma signals of the current frame and previous frame received from an input means, outputting line comb chroma signals;

subtracting the line comb chroma signals;

extracting the magnitude of the line comb chroma signals to generate an intermediate chroma motion CD_p ;

low pass filtering the line comb chroma signals to smoothen transitions;

eliminating possible noise interference of the magnitude;

multiplying the magnitude with a gain; and

clipping the magnitude to an appropriate motion range to generate chroma motion CD .

22. The process of claim 21, wherein the step of detecting U and V chroma motions between a current frame and a previous frame further comprises:

taking and duplicating the maximum between the step of extracting the magnitude of the line comb chroma signals to generate an intermediate chroma motion CD_p and the step of low pass filtering the line comb chroma signals to smoothen transitions.

23. The process of claim 21, wherein the current frame and previous frame are frame n and frame $n-1$ respectively for NTSC standard or are frame n and frame $n-2$ respectively for PAL standard.

24. The process of claim 16, wherein the step of detecting presence of luminance residue on U and V chroma components in a current frame and a previous frame comprises:

forward diagonally filtering three line chroma signals of the current frame and previous frame received from an inputting means;

backward diagonally filtering three line chroma signals of frames n and $n-1$ received from an inputting means;

subtracting the filtered signals;

extracting the magnitude of the filtered signals;

selecting the maximum of the forward or backward contribution to generate an intermediate high frequency signal CF_p ;

low pass filtering the intermediate high frequency signal to smooth transitions;

coring the intermediate high frequency signals to eliminate small noise;

multiplying the filtered output with a gain; and

clipping the signal to generate high frequency signal CF .

25. The process of claim 24, wherein the step of detecting presence of luminance residue on U and V chroma components in a current frame and a previous frame comprises:

taking and duplicating the maximum between the step of selecting the maximum of the forward or backward contribution to generate an intermediate high frequency signal CF_p and the step of low pass filtering the intermediate high frequency signal to smooth transitions.

26. The process of claim 24, wherein the current frame and previous frame are frame n and frame $n-1$ respectively for NTSC standard or are frame n and frame $n-2$ respectively for PAL standard.

27. The process of claim 16, wherein the step of detecting luminance and chroma motion between a current frame and a plurality of previous frames comprises:

receiving signals from the current frame and the plurality of previous frames via an inputting means, said computing circuit computing an intermediate motion values YCD_p ;

smoothing the motion values;

coring the motion values;

multiplying the motion values with a gain; and

clipping the motion values to generate YC motion signal, YCD .

28. The process of claim 27, wherein the current frame and the plurality of previous frames are frame n and frames $n-1$, $n-2$, and $n-3$ respectively for NTSC standard so that the intermediate motion values YCD_p is computed according to the equation below:

$$YCD_p = \text{Max} \left\{ \left| C_{m,n} + C_{m,n-1} - C_{m,n-2} - C_{m,n-3} \right|, \left| C_{m,n} - C_{m,n-1} - C_{m,n-2} + C_{m,n-3} \right| \right\};$$

wherein the current frame and the plurality of previous frames are frame n and frame $n-1$, $n-2$, $n-3$, $n-4$ respectively for PAL standard so that the intermediate motion values YCD_p is computed according to the equation below:

$$YCD_p = \text{Max} \left\{ \left| C_{m,n} - C_{m,n-1} + C_{m,n-2} - C_{m,n-3} \right|, \left| C_{m,n-1} - C_{m,n-2} + C_{m,n-3} - C_{m,n-4} \right| \right\}.$$

29. The process of claim 27, wherein the step of detecting luminance and chroma motion between a current frame and a plurality of previous frames further optionally comprises:

taking and duplicating the maximum between the step of computing and the step of smoothing the motion values.

30. A luminance motion detector comprises:

at least two vertical low pass filters for low pass filtering at least three line luminance signals of a current frame and a previous frame received from an input means, outputting line comb signals;

a subtractor coupled to the at least two vertical low pass filters to subtract the line comb signals;

a horizontal low pass filter coupled to the subtractor for subsequently low pass filtering the line-comb signal differences to exclude possible interference of chroma residue;

an absolute circuit coupled to the horizontal low pass filter for extracting the magnitude of the line-comb signals;

a coring circuit coupled to the absolute circuit for eliminating possible noise interference the magnitude;

a multiplier coupled to the coring circuit for multiplying the magnitude by a gain;
and

a saturation circuit coupled to the multiplier for clipping an appropriate motion range of the magnitude to generate low frequency luminance motion YM_n .

31. The luminance motion detector of claim 30, wherein the at least two vertical low pass filters have low pass frequency characteristics not exceeding the lower end of the overlapping frequency band of chroma and luminance signal or band-stop frequency characteristics covering the chroma band.

32. The luminance motion detector of claim 30, wherein the current frame and previous frame are frame n and frame $n-1$ respectively for NTSC standard or are frame n and frame $n-2$ respectively for PAL standard.

33. A chroma motion detector comprises:

at least two vertical low pass filters for low pass filtering at least three line chroma signals of a current frame and a previous frame received from an input means, outputting line comb chroma signals;

a subtractor coupled to the at least two chroma motion detectors for subtracting the line comb chroma signals;

an absolute circuit coupled to the subtractor for extracting the magnitude of the line comb chroma signals to generate an intermediate chroma motion CD_p ;

a horizontal low pass filter coupled to the absolute circuit for low pass filtering the line comb chroma signals to smoothen transitions;

a coring circuit coupled to the horizontal low pass filter for eliminating possible noise interference of the magnitude;

a multiplier coupled to the coring circuit for multiplying the magnitude with a gain; and

a saturation circuit coupled to the multiplier for clipping the magnitude to an appropriate motion range to generate chroma motion CD .

34. The chroma motion detector of claim 33, further optionally comprising a Maxd circuit between the absolute circuit and the horizontal low pass filter for taking and duplicating the maximum.

35. The chroma motion detector of claim 33, wherein the current frame and previous frame are frame n and frame $n-1$ respectively for NTSC standard or are frame n and frame $n-2$ respectively for PAL standard.

36. A smoothness detector comprises:

at least two forward diagonal high pass filters for diagonally filtering three line chroma signals of a current frame and a previous frame received from an inputting means;

at least two backward diagonal high pass filters for diagonally filtering three line chroma signals of frames n and $n-1$ received from an inputting means;

at least two subtractors coupled to the high pass filters for subtracting the filtered signals;

at least two absolute circuits coupled to the at least two subtractors for extracting the magnitude of the filtered signals;

a max circuit coupled to the at least two absolute circuits for selecting the maximum of the forward or backward contribution to generate an intermediate high frequency signal CF_p ;

a horizontal low pass filter coupled to the max circuit for low pass filtering the intermediate high frequency signal to smooth transitions;

a coring circuit coupled to the horizontal low pass filter for coring the intermediate high frequency signals to eliminate small noise;

a multiplier coupled to the coring circuit for multiplying the filtered output with a gain; and

a saturation circuit coupled to the multiplier for clipping the signal to generate high frequency signal CF .

37. The smoothness detector of claim 36, further optionally comprising a Maxd circuit between the max circuit and the horizontal low pass filter for taking and duplicating the maximum.

38. The smoothness detector of claim 36, wherein the current frame and previous frame are frame n and frame n-1 respectively for NTSC standard or are frame n and frame n-2 respectively for PAL standard.

39. A phase motion detector comprises:

a computing circuit receiving signals from a current frame and a plurality of previous frames via an inputting means, said computing circuit computing an intermediate motion values YCD_p ;

a horizontal low pass filter coupled to the computing circuit for smoothing the motion values;

a coring circuit coupled to the horizontal low pass filter for coring the motion values;

a multiplier coupled to the coring circuit for multiplying the motion values with a gain; and

a saturation circuit coupled to the multiplier for clipping the motion values to generate YC motion signal, YCD .

40. The phase motion detector of claim 39, wherein the current frame and the plurality of previous frames are frame n and frames n-1, n-2, and n-3 respectively for NTSC standard so that the intermediate motion values YCD_p is computed according to the equation below:

$$YCD_p = \text{Max} \left\{ \left| C_{m,n} + C_{m,n-1} - C_{m,n-2} - C_{m,n-3} \right|, \left| C_{m,n} - C_{m,n-1} - C_{m,n-2} + C_{m,n-3} \right| \right\};$$

wherein the current frame and the plurality of previous frames are frame n and frame n-1, n-2, n-3, n-4 respectively for PAL standard so that the intermediate motion values YCD_p is computed according to the equation below:

$$YCD_p = \text{Max} \left\{ \left| C_{m,n} - C_{m,n-1} + C_{m,n-2} - C_{m,n-3} \right|, \left| C_{m,n-1} - C_{m,n-2} + C_{m,n-3} - C_{m,n-4} \right| \right\}.$$

41. The phase motion detector of claim 39, further optionally comprising a Maxd circuit between the computing circuit and the horizontal low pass filter for taking and duplicating the maximum.

42. A baseband YC separation circuitry for video signal processing comprising:

- a cross luminance suppression circuit for suppressing dot crawl artifacts or chroma residue present in Y signal;
- a cross chroma (U) suppression circuit for suppressing cross colour artifacts or luminance residue present in U signals;
- a cross chroma (V) suppression circuit for suppressing cross colour artifacts or luminance residue present in V signals; and
- a baseband motion detector for differentiating between the moving and the stationary pixels such that an optimum comb filter can be selected to maximize effectiveness of YC separation;

thereby the baseband YC separation circuitry receives Y_{in} , U_{in} and V_{in} input signals separately and outputs the clean Y_{out} , U_{out} and V_{out} signals.

43. The baseband YC separation circuitry of claim 42, wherein the cross luminance suppression circuit comprises:

- an inter-line correlator for detecting the relative chroma correlation between the current and next line and current and previous line, such that a line comb does not filter across contrasting colour regions, said inter-line correlator comprising:

- a narrowband filter for isolating the sub-band of the YC interleave frequency band;

- at least one gradient circuit coupled to the narrowband filter for computing the gradients of the current and next line, $G_{x,m,m+1}$, and current and previous line, $G_{x,m,m-1}$;

- at least one horizontal low pass filter coupled to the gradient circuit for low pass filtering for continuity; and

- a function circuit coupled to the horizontal low pass filter for generating the weight between the current and previous line K_{2D} ;

- a line comb for extracting chroma residues from the Y signal comprising:

- a wideband filter for filtering out the low and high frequency signal and retaining only the frequency band with interleave Y and C signal;

- at least one subtractor for computing the inter-line differences; and

- a mixer for mixing corresponding to K_2D signal from the inter-line correlator;
- a frame comb for subtracting the previous frame signal $Y_{m,n-1}$ from the current frame signal $Y_{m,n}$ using a subtractor to generate frame comb output;
- a mixer circuit for extracting the residual chroma signal using motion value, K_motion from the baseband motion detector;
- a subtractor for subtracting the residual chroma signal from input luminance signal, Y_{in} ; and
- a saturation circuit for clipping the output to defined pixel range so as to generate the final clean luminance signal.

44. The baseband YC separation circuitry of claim 42, wherein the cross chroma suppression circuits comprises:

- an inter-line correlator for detecting the relative chroma correlation between the current and next line and current and previous line, said inter-line correlator comprising:
 - at least one gradient circuit for computing the gradients of current and next line, $G_{x,m,m+1}$, and current and previous line, $G_{x,m,m-1}$;
 - at least one horizontal low pass filters for subsequently filtering the gradients; and
 - a function circuit for generating the weight between the current and previous chroma line, K_2D ;
- a chroma line comb for removing the redundant luminance residue from the U_{in} or V_{in} signal; said chroma line comb comprising:
 - at least one adder for averaging the inter-line differences; and
 - a mixer for mixing differences corresponding to K_2D signal from the inter-line correlator;
 - a frame comb for adding the previous frame signal $C_{m,n-1}$ from the current frame signal $C_{m,n}$ using an adder to generate frame comb output C_3D ;
 - a mixer circuit for using the motion value, K_motion from the baseband motion detector to generate the final 3D value, C_{out} ; and
 - a saturation circuit for clipping the final 3D value to a valid pixel range.

45. The baseband YC separation circuitry of claim 42, wherein the baseband motion detector comprising:

- a luminance motion detector for detecting the low frequency luminance motion between a current frame and a previous frame;

- at least two chrominance motion detector for detecting U and V chroma motions between a current frame and a previous frame;

- a smoothness detector for detecting presence of luminance residue on U and V chroma components in a current frame and a previous frame; and

- a phase motion detector for detecting luminance and chroma motion between a current frame and a plurality of previous frames.

46. A video signal processing system used in an electronic article, said system comprising:

- a front end digital decoder for decoding a composite input signals to generate component Y, U and V signals, said front end digital decoder comprising:

 - a synchronization unit for capturing the video synchronization signals and locking the system clock to the frequency and phase of the incoming signal using the chroma burst;

 - an input sample rate convertor for re-sampling the acquisition sample rate;

 - a YC separation circuit for separating chroma and luminance signal from the composite signal;

 - a chroma demodulator for demodulating the chroma signal according chroma phase lock loop; and

 - an output sample rate convertor and scaler for re-sampling the separated signals to output sampling rate domain and scaling the video signal to required dynamics; and

- a baseband YC separation module for receiving the component signals from the decoder for further 3D comb filtering.

47. The video signal processing system used in an electronic article of claim 46, wherein the baseband YC separation module comprises a 3D comb filter using a mix of frame comb and line comb controlled by a motion detector.

48. The video signal processing system used in an electronic article of claim 46, wherein the baseband YC separation module comprises a 2D comb filter with a 3-line comb controlled by an inter-line correlator.

49. The video signal processing system used in an electronic article of claim 46, wherein the baseband YC separation module comprises a set of complementary or non-complementary filters around the chroma subcarrier frequency with band-stop or notch filter for the Y output and band-pass filter for the C output.

50. The video signal processing system used in an electronic article of claim 46, wherein the baseband YC separation module may operate independent of the front-end separation circuitry.

51. The video signal processing system used in an electronic article of claim 46, wherein the electronic article includes television, display sets, video CD player, DVD players or recorders and set-top-boxes with composite sources or sources that have composite conversion in at least one stage of processing prior to input.

52. A chip comprising a computer executable medium embedded therein a video signal processing system, said system comprising:

- a front end digital decoder for decoding a composite input signals to generate component Y, U and V signals, said front end digital decoder comprising:

- a synchronization unit for capturing the video synchronization signals and locking the system clock to the frequency and phase of the incoming signal using the chroma burst;

- an input sample rate convertor for re-sampling the acquisition sample rate;

- a YC separation circuit for separating chroma and luminance signal from the composite signal;

- a chroma demodulator for demodulating the chroma signal according chroma phase lock loop; and

an output sample rate convertor and scaler for re-sampling the separated signals to output sampling rate domain and scaling the video signal to required dynamics; and

a baseband YC separation module for receiving the component signals from the decoder for further 3D comb filtering;

whereby the chip is used either alone or in conjunction with an electronic article.

53. The chip of claim 52, wherein the baseband YC separation module comprises a 3D comb filter using a mix of frame comb and line comb controlled by a motion detector.

54. The chip of claim 52, wherein the baseband YC separation module comprises a 2D comb filter with a 3-line comb controlled by an inter-line correlator.

55. The chip of claim 52, wherein the baseband YC separation module comprises a set of complementary or non-complementary filters around the chroma subcarrier frequency with band-stop or notch filter for the Y output and band-pass filter for the C output.

56. The chip of claim 52, wherein the baseband YC separation module may operate independent of the front-end separation circuitry.

57. The chip of claim 52, wherein the electronic article includes television, display sets, video CD player, DVD players or recorders and set-top-boxes with composite sources or sources that have composite conversion in at least one stage of processing prior to input.