BRIEF DESCRIPTION

According to a first aspect of the present invention, there is provided a method comprising: via computer processing hardware, performing image processing operations of: receiving reference image information, the reference image information defining a grid of multiple elements at a given resolution; receiving compensation information for an image element being reproduced in a compensated image at the given resolution, the compensated image including display elements, settings of the display elements in the compensated image derived at least in part from the reference image information;

processing the received compensation information to produce a set of coordinates indicating a corresponding off-grid location of the image element in the grid; calculating a value for the corresponding off-grid location of the image element based on a group of multiple elements in the ~~grid~~reference image; and assigning the value to the image element in the compensated image.

According to a second aspect of the present invention, there is provided a method comprising: via computer processor hardware, performing image-processing operations of: receiving settings information for a first image, the first image including a set of multiple display elements; receiving motion compensation information for a given display element in a second image, the motion compensation information indicating ~~a~~ an off-center coordinate location within a particular display element in the first image to which the given display element pertains; utilizing the off-center coordinate location as a basis from which to select a grouping of multiple display elements in the first image; and generating a setting for the given display element in the second image based on settings of the multiple display elements in the grouping.

According to a third aspect of the present invention, there is provided computer-readable hardware storage having instructions stored thereon, the instructions, when carried out by ~~at least one processing device~~computer processor hardware, causes the ~~at least one processing device~~computer processor hardware to perform operations of: receiving reference image information, the reference image information defining a grid of multiple elements at a given resolution; receiving compensation information for an image element in a compensated image, settings of display elements in the compensated image derived at least in part from the reference image information; processing the received compensation information to produce a set of coordinates indicating a corresponding off-

grid location of the image element in the grid; calculating a value for the corresponding off-grid location of the image element based on a group of multiple elements in the grid; and assigning the value to the image element in the compensated image.

According to a fourth aspect of the present invention, there is provided computer-readable hardware storage having instructions stored thereon, the instructions, when carried out by computer processor hardware~~at least one processing device~~, causes the computer processor hardware~~at least one processing device~~ to perform operations of: receiving settings information for a first image, the first image including a set of multiple display elements; receiving motion compensation information for a given display element in a second image, the motion compensation information indicating a coordinate location within a particular display element in the first image to which the given display element pertains; utilizing the coordinate location as a basis from which to select a grouping of multiple display elements in the first image; and generating a setting for the given display element in the second image based on settings of the multiple display elements in the grouping.

According to a fifth aspect of the present invention, there is a computer system comprising: computer processor hardware; and a hardware storage resource coupled to the computer processor hardware, the hardware storage resource storing instructions that, when executed by the at computer processor hardware, causes the computer processor hardware to perform operations of: receiving reference image information, the reference image information defining a grid of multiple elements at a given resolution; receiving compensation information for an image element in a compensated image, settings of display elements in the compensated image derived at least in part from the reference image information; processing the received compensation information to produce a set of coordinates indicating a corresponding off-grid location of the image element in the grid; calculating a value for the corresponding off-grid location of the image element based on a group of multiple elements in the grid; and assigning the value to the image element in the compensated image. Embodiments herein deviate with respect to conventional systems and methods, providing novel methods to estimate, encode and leverage motion information so as to generate a suitable prediction of a current image (or "target image") based on motion compensation of a reference image, hence supporting methods such as motion estimation, motion compensation, signal encoding, signal quality enhancement

(e.g., denoising, super-resolution, etc.), signal interpolation (e.g., increase of frame-rate), special effects, computer graphics, medical imaging, computer vision, augmented reality applications, etc.

One embodiment herein includes a method for calculating or predicting the value of an element of a target image based on the value of an arbitrary location of a reference image, whereby such arbitrary location is expressed with fractional coordinates (such as floating point numbers, high-precision fixed-point numbers, real numbers, non-integer numbers, etc.) independent of the actual sample grid (i.e., resolution) of the reference image used as a basis to reconstruct a rendition of the image. In contrast to pre-calculating and producing a supersampled reference image at a higher resolution and then performing motion compensation by means of an integer coordinate system based on the supersampled grid, certain embodiments illustrated herein do not need to pre-calculate any supersampled rendition of the reference image and instead calculate reference elements on-the-fly at any arbitrary location in the reference image (e.g., without limitation, via on-the-fly resampling techniques).

According to embodiments herein, motion compensation can be effectively implemented using a substantially continuous coordinate system and effectively supporting motion compensation of very subtle movements (e.g., if necessary, even smaller than $1/10^{th}$ of a pel) with relatively limited buffer memory cost and computational cost. Essentially, motion compensation according to embodiments herein allows for extremely high precision (e.g., capturing movements of less than $1/100^{th}$ of a pel) and may leverage resampling operations performed on the fly, without the need of storing large reference images at higher resolutions.

Embodiments herein may be useful in conjunction with traditional motion compensation

CLAIMS

1. A method comprising:

via computer processor hardware, performing image processing operations of:

receiving reference image information, the reference image information defining a grid of multiple elements at a given resolution;

receiving compensation information for an image element being reproduced in a compensated image at the given resolution, the compensated image including display elements, settings of the display elements in the compensated image derived at least in part from the reference image information;

processing the received compensation information to produce a set of coordinates indicating a corresponding off-grid location of the image element in the grid;

calculating a value for the corresponding off-grid location of the image element based on a group of multiple elements in the ~~grid~~reference image; and

assigning the value to the image element in the compensated image.

2. The method as in claim 1, wherein the coordinates indicating the corresponding off-grid location are expressed with a ~~substantially~~ higher resolution than the given resolution of the grid.

3. The method as in claim 1, wherein calculating the value includes:

applying an algorithm to identify which of the multiple elements in the grid to include in the group, the group of multiple elements disposed in a vicinity of the corresponding off-grid location, the algorithm applying mathematical operations to settings of the group of multiple elements to derive the value.

4. The method as in claim 1, wherein the set of coordinates indicating the corresponding off-grid location are expressed via numbers representing quantities in a real domain.

5. The method as in claim 4, wherein the set of coordinates indicating the corresponding off-grid location has a ~~sufficiently high~~ resolution that can be used to specify an offset with respect to on-grid locations in the grid by less than $1/32^{nd}$ of a display element in the

grid.

~~6. The method as in claim 1, wherein the resolution of the reference image information is substantially the same as a resolution of the compensated image.~~

~~7~~6. The method as in claim 1, wherein calculating the value includes applying floating point operations in a real domain.

~~8~~7. The method as in claim 1, wherein calculating the value includes applying mathematical operations with fixed-point numbers representing quantities in a real domain.

~~9~~8. The method as in claim 1, wherein the compensation information comprises parameters expressed by numbers representing quantities in a real domain.

~~10~~9. The method as in claim 1, wherein calculating the value includes executing a shader in a Graphics Processing Unit.

~~11~~10. The method as in claim 1, wherein calculating the value includes executing at least one resampling operation.

~~12~~11. The method as in claim 1, wherein processing the received compensation information includes:

applying linear combinations to the coordinates of the image element according to parameters specified in the received compensation information to produce the set of coordinates in the reference image for the image element; and

applying linear combinations to coordinates according to the same parameters to produce a respective set of coordinates in the reference image for each of multiple display elements in the compensated image.

~~13~~12. The method as in claim 1, wherein processing the received compensation information includes:

calculating a vector in homogenous coordinates corresponding to the set of coordinates associated with the image element in the compensated image; and

multiplying the vector by a matrix, wherein the coefficients in the matrix are specified at least in part based on the compensation information.

~~14~~13. The method as in claim 1 further comprising:

calculating the set of coordinates as coordinates (x^T, y^T), the coordinates (x^T, y^T) specifying the off-grid location of the image element, the image element residing at location (x, y) in the compensated image, the coordinates (x^T, y^T) calculated by performing sums and multiplications of x and y with six coefficients a, b, c, d, e and f, according to the following formula:

$$\begin{bmatrix} x^T & y^T \end{bmatrix} = \begin{bmatrix} a \cdot x + c \cdot y + e & b \cdot x + d \cdot y + f \end{bmatrix}.$$

~~15~~14. The method as in claim ~~12~~11, wherein at least one element of the multiple display elements in the compensated image with ~~respected~~ respective coordinates in the reference image calculated based on a same set of parameters is not contiguous with other display elements of the multiple display elements.

~~16~~15. The method as in claim 1, wherein the compensation information comprises at least one parameter selected from a group comprising: scaling, rotation and offset.

~~17~~16. The method as in claim ~~16~~15, wherein the compensation information comprises at least one parameter selected from the group comprising: scaling, rotation, offset, shearing, perspective change.

~~18~~17. The method as in claim 1 further comprising:

calculating the set of coordinates as coordinates (x^T, y^T), the coordinates (x^T, y^T) specifying the off-grid location of the image element, the image element residing at

location (x, y) in the compensated image, the coordinates (x^T, y^T) calculated by performing sums and multiplications of x and y with eight coefficients a, b, c, d, e, f, g and h, according to the following formula:

$$\begin{bmatrix} x^T & y^T \end{bmatrix} = \begin{bmatrix} \frac{a \cdot x + c \cdot y + e}{g \cdot x + h \cdot y + 1} & \frac{b \cdot x + d \cdot y + f}{g \cdot x + h \cdot y + 1} \end{bmatrix}.$$

~~19~~18. The method as in claim 1 further comprising:

assigning a default value to a respective set of coordinates that specify a location outside of the grid and with a distance from a closest sample of the grid beyond a given threshold value.

~~20. The method as in claim 1, wherein the compensated image has a higher resolution than the grid of multiple elements.~~

~~21. The method as in claim 1, wherein the compensated image has a lower resolution than the grid of multiple elements.~~

~~22~~19. The method as in claim 1, wherein the compensated image is a two-dimensional image.

~~23~~20. The method as in claim 1, wherein the compensated image is a volumetric image.

~~24~~21. The method as in claim 1, wherein the compensated image is a mono-dimensional image.

~~25~~22. A method comprising:

via computer processor hardware, performing image-processing operations of:

receiving settings information for a first image, the first image including a set of multiple display elements;

receiving motion compensation information for a given display element in a second

image, the motion compensation information indicating an off-center ~~a~~ coordinate location within a particular display element in the first image to which the given display element pertains;

utilizing the off-center coordinate location as a basis from which to select a grouping of multiple display elements in the first image; and

generating a setting for the given display element in the second image based on settings of the multiple display elements in the grouping.

~~26~~23. The method as in claim ~~25~~22, wherein generating the setting for the given display element includes:

calculating the setting for the given display element based at least in part on distances of the multiple display elements in the grouping with respect to the off-center coordinate location in the particular display element.

~~27~~24. The method as in claim ~~25~~22, wherein generating the setting for the given display element includes:

calculating the setting for the given display element based at least in part on a settings of the multiple display elements in the grouping.

~~28~~25. The method as in claim ~~25~~22, wherein the off-center coordinate location represents a centroid from which to generate the setting of the given display element; and wherein generating the setting for the given display element includes:

producing weighted values, the weighted values varying depending on a respective distance between the centroid of the given display element and a respective centroid of an element in the grouping; and

applying the weighted values to settings of the display elements in the grouping to produce the setting for the given display element.

~~29. The method as in claim 25, wherein the coordinate location specifies a location other than a center of the particular display element in the first image.~~

~~30~~26. The method as in claim ~~25~~22, wherein a resolution of the first image is ~~substantially~~ equal to a resolution of the second image.

~~31~~27. The method as in claim ~~25~~22, wherein a resolution of the first image is ~~substantially~~ different ~~than~~ to a resolution of the second image.

~~32~~28. The method as in claim ~~25~~22, wherein utilizing the off-center coordinate location as a basis from which to select the grouping of multiple display elements in the first image includes:

creating the grouping of multiple display elements to include the particular display element and a display element in the first image located in a vicinity of the particular display element; and

interpolating the setting of the given display element based on: i) a proximity of the off-center coordinate location with respect to a centroid of the particular display element and a centroid of the display element in the vicinity of the particular display element, ii) a setting of the particular display element, and iii) a setting of the display element located in the vicinity of the particular display element.

~~33~~29. The method as in claim ~~25~~22, wherein the first image is a reference image; and wherein the set of multiple display elements represents at least a portion of an object present in the first image.

~~34~~30. The method as in claim 25, wherein the off-center coordinate location is offset with respect to a centroid of the particular display element by a fraction of a display element greater than zero but less than 1.

31~~35~~. Computer-readable hardware storage having instructions stored thereon, the instructions, when carried out by computer processor hardware, ~~at least one processing device,~~ causes the ~~at least one processing device~~ computer processor hardware to perform operations of:

receiving reference image information, the reference image information defining a grid

of multiple elements at a given resolution;

receiving compensation information for an image element in a compensated image, settings of display elements in the compensated image derived at least in part from the reference image information;

processing the received compensation information to produce a set of coordinates indicating a corresponding off-grid location of the image element in the grid;

calculating a value for the corresponding off-grid location of the image element based on a group of multiple elements in the grid; and

assigning the value to the image element in the compensated image.

~~36~~32. Computer-readable hardware storage having instructions stored thereon, the instructions, when carried out by ~~at least one processing device~~computer processor hardware, causes the ~~at least one processing device~~computer processor hardware to perform operations of:

receiving settings information for a first image, the first image including a set of multiple display elements;

receiving motion compensation information for a given display element in a second image, the motion compensation information indicating a coordinate location within a particular display element in the first image to which the given display element pertains;

utilizing the coordinate location as a basis from which to select a grouping of multiple display elements in the first image; and

generating a setting for the given display element in the second image based on settings of the multiple display elements in the grouping.

~~37~~33. A computer system comprising:

computer processor hardware; and

a hardware storage resource coupled to the computer processor hardware, the hardware storage resource storing instructions that, when executed by the at computer processor hardware, causes the computer processor hardware to perform operations of:

receiving reference image information, the reference image information defining a grid of multiple elements at a given resolution;

receiving compensation information for an image element in a compensated image, settings of display elements in the compensated image derived at least in part from the reference image information;

processing the received compensation information to produce a set of coordinates indicating a corresponding off-grid location of the image element in the grid;

calculating a value for the corresponding off-grid location of the image element based on a group of multiple elements in the grid; and

assigning the value to the image element in the compensated image.

~~38~~34. The method as in claim ~~37~~33, wherein the set of coordinates indicating the corresponding off-grid location are expressed via numbers representing quantities in a real domain.

35. The method as in claim 22, wherein utilizing the off-center coordinate location further comprises:

selecting the grouping of multiple display elements in the first image based on a respective nearness of each of the multiple display elements with respect to the off-center coordinate location.

36. The method as in claim 35, wherein the multiple display elements includes a first display element and a second display element; and

wherein generating the setting for the given display element in the second image further comprises:

producing a first length value, the first length value representing a respective length between the off-center coordinate location and the first display element; and

producing a second length value, the second value representing a respective length between the off-center coordinate location and the second display element.

37. The method as in claim 36, wherein generating the setting for the given display element further comprises:

deriving a first weight value based upon a magnitude of the first length value;

deriving a second weight value based upon a magnitude of the second length value;

obtaining a first setting, the first setting representing a setting of the first display element in the first image;

obtaining a second setting, the second setting representing a setting of the second display element in the first image;

multiplying the first setting by the first weight value to produce a first weighted component;

multiplying the second setting by the second weight value to produce a second weighted component; and

summing the first weighted component and the second weighted component to produce the setting for the given display element in the second image.

38. The method as in claim 22, wherein an overlay coverage region of the given display element at the off-center coordinate location in the first image overlaps at least a portion of the multiple display elements in the grouping.

39. The method as in claim 38, wherein the overlay coverage region of the given display element is offset with respect to each of the multiple display element in the grouping.

40. The method as in claim 38, wherein at least one of the multiple display element in the grouping reside completely outside of the overlay coverage region of the given display element in the first image.

41. The method as in claim 22, wherein the grouping ot the multiple display elements in the first image and the given display element in the second image represent a same portion of an object present in the first image and the second image.

42. The method as in claim 22, wherein the multiple display elements in the grouping represents a portion of an object captured in the first image; and

wherein the given display element in the second image represents the portion of

the object in the second image.