United States Patent Application Publication 20250267236
Kind Code A1
Publication Date August 21, 2025
Inventor(s) Woodman; Nicholas D. et al.

CONVERSION BETWEEN ASPECT RATIOS IN CAMERA

Abstract

A camera system captures an image in a source aspect ratio and applies a transformation to the input image to scale and warp the input image to generate an output image having a target aspect ratio different than the source aspect ratio. The output image has the same field of view as the input image, maintains image resolution, and limits distortion to levels that do not substantially affect the viewing experience. In one embodiment, the output image is non-linearly warped relative to the input image such that a distortion in the output image relative to the input image is greater in a corner region of the output image than a center region of the output image.

Inventors: **Woodman; Nicholas D. (Big Sky, MT), Chawla; Sumit (San Mateo, CA), Segapelli; Loic (Oakland, CA), Campbell; Scott Patrick (Belmont, CA)**

Applicant: **GoPro, Inc.** (San Mateo, CA)

Family ID: **1000008586682**

Appl. No.: **19/203017**

Filed: **May 08, 2025**

Related U.S. Application Data

parent US continuation 18364792 20230803 parent-grant-document US 12302028 child US 19203017
parent US continuation 17536699 20211129 parent-grant-document US 11722631 child US 18364792
parent US continuation 17075923 20201021 parent-grant-document US 11190709 child US 17536699
parent US continuation 16456613 20190628 parent-grant-document US 10819918 child US 17075923
parent US continuation 16023675 20180629 parent-grant-document US 10368013 child US 16456613
parent US continuation 15492738 20170420 parent-grant-document US 10015413 child US 16023675
parent US continuation 15011253 20160129 parent-grant-document US 9674429 child US 15492738
parent US continuation 14536315 20141107 parent-grant-document US 9294671 child US 15011253
parent US continuation 14180887 20140214 parent-grant-document US 8917329 child US 14536315
us-provisional-application US 61869029 20130822

Publication Classification

Int. Cl.: **H04N5/262** (20060101); **G06T3/18** (20240101); **G06T3/20** (20060101); **G06T3/40** (20240101); **G06T3/4069** (20240101); **G06T3/4084** (20240101); **G09G5/00** (20060101); **H04N7/01** (20060101); **H04N21/2343** (20110101); **H04N21/4402** (20110101); **H04N23/80** (20230101)

U.S. Cl.:

CPC **H04N5/2628** (20130101); **G06T3/18** (20240101); **G06T3/4069** (20130101); **G09G5/005** (20130101); **H04N7/0122** (20130101); **H04N21/234372** (20130101); **H04N23/80** (20230101); G06T3/20 (20130101); G06T3/40 (20130101); G06T3/4084 (20130101); G09G2340/0442 (20130101); H04N21/440272 (20130101)

Background/Summary

BACKGROUND
[0001] Converting between aspect ratios is a common problem in the field of image and video processing. For example, a display that displays images according to a 16:9 aspect ratio may receive images natively captured according to a 4:3 aspect ratio and perform an aspect ratio conversion to fit the image to the display. Conventional conversion techniques such as cropping, linearly scaling, and padding each result in a perceivable reduction in the quality of the image or video. For example, cropping removes content from the image and reduces the field of view of the image. Linear scaling maintains the full field of view but introduces perceivable distortion into the image. For example, if an image is vertically compressed and/or horizontally stretched to convert from a 4:3 to a 16:9 aspect ratio, features in scene will appear “short and fat” relative to the original image. Padding maintains the full field of view without distortion, but results in unused display space around the sides and/or top of the image, thus rendering an image that appears too small relative to the display.
SUMMARY
[0002] An input image having a source aspect ratio may be obtained. The input image may include pixels located at input positions. An output image

may be generated by applying a transformation to the input image. The output image may have a target aspect ratio different than the source aspect ratio. The output image may include the pixels located at output positions. The transformation may include a linear scaling to uniformly stretch or compress the input image and a non-linear warping to non-uniformly warp the input image. The linear scaling and the non-linear warping may change the pixels from being located at the input positions in the input image to output positions in the output image. The nonlinear warping may include: a horizontal warping that changes pixel positions as a function of horizontal coordinates of the pixels, an amount of horizontal change in pixel positions characterized by a horizontal distortion offset that an individual pixel moves away from a first reference edge; and a vertical warping that changes the pixel positions as a function of vertical coordinates of the pixels, an amount of vertical change in pixel positions characterized by a vertical distortion offset that the individual pixel moves away from a second reference edge different from the first reference edge.
[0003] In some embodiments, the first reference edge may include a right edge or a left edge. and the second reference edge may include a top edge or a bottom edge.
[0004] In some embodiments, the linear scaling may change the source aspect ratio to the target aspect ratio.
[0005] In some embodiments, the nonlinear warping may not offset pixels along edges to prevent padding in the output image.
[0006] In some embodiments, the vertical warping may change the pixel positions further as a function of the horizontal coordinates of the pixels.
[0007] In some embodiments, magnitudes of distortion performed by the horizontal warping may be horizontally symmetrical.
[0008] In some embodiments, degradation in image quality caused by the horizontal warping may be compensated for by the vertical warping.
[0009] In some embodiments, the horizontal warping may be tuned in combination with the vertical warping to preserve width of objects throughout a horizontal plane.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0010] FIG. **1** is a block diagram illustrating an embodiment of a camera system.
[0011] FIG. **2**A is a flowchart illustrating an embodiment of a process for converting an image from a source aspect ratio to a target aspect ratio.
[0012] FIG. **2**B is set of example images being converted from a source aspect ratio to a target aspect ratio.
[0013] FIG. **3** is a first set of example images showing an original image in a source aspect ratio, a cropped image converted to a target aspect ratio using a cropping technique, and a non-linear warped image converted to the target aspect ratio using a non-linear warping technique.
[0014] FIG. **4** is a second set of example images showing an original image in a source aspect ratio, a cropped image converted to a target aspect ratio using a cropping technique, and a non-linear warped image converted to the target aspect ratio using a non-linear warping technique.
[0015] FIG. **5** is a graph illustrating an embodiment of a function for applying a horizontal warp to an image.
[0016] FIG. **6** is a graph illustrating an embodiment of a function for applying a vertical warp to an image.
DETAILED DESCRIPTION
[0017] The Figures (FIGS.) and the following description relate to preferred embodiments by way of illustration only. It should be noted that from the following discussion, alternative embodiments of the structures and methods disclosed herein will be readily recognized as viable alternatives that may be employed without departing from the principles of what is claimed.
[0018] Reference will now be made in detail to several embodiments, examples of which are illustrated in the accompanying figures. It is noted that wherever practicable similar or like reference numbers may be used in the figures and may indicate similar or like functionality. The figures depict embodiments of the disclosed system (or method) for purposes of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles described herein.
Overview
[0019] A camera system comprises an image sensor, a processor, and a non-transitory computer-readable storage medium that stores instructions executable by the processor. The image sensor captures an input image having a source aspect ratio. The processor applies a transformation to the input image to scale and warp the image to generate an output image having a target aspect ratio different than the source aspect ratio. The output image has the same field of view as the input image, maintains image resolution, and limits distortion to levels that do not substantially affect the viewing experience. In one embodiment, the output image is non-linearly warped relative to the input image such that a distortion in the output image relative to the input image is greater in a corner region of the output image than a center region of the output image. The processor outputs the output image having the target aspect ratio.
[0020] In one embodiment, the aspect ratio conversion is performed directly on the camera itself rather than in an external post-processing device, such as the display device. This enables the camera to output images directly to a display in the desired target aspect ratio without requiring conversion by the display device. For example, a camera that natively captures images according to a 4:3 aspect ratio can perform conversion and output the images according to a 16:9 aspect ratio that may be displayed directly on a 16:9 display device. Furthermore, in one embodiment, the conversion may occur in substantially real-time such that images captured in the source aspect ratio can be outputted in the target aspect ratio with substantially no delay.
[0021] Beneficially, since the aspect ratio conversion preserves the entire field of view of the image, the converted image can be reverted back to its original aspect ratio without any loss of field of view or resolution. Furthermore, since the aspect ratio discrepancy is handled by the camera system, the end user needs not to make any additional adjustments apart from selecting the desired output video format on the camera. The embodiments described herein may apply to both individual images and video (which comprises a sequence of images (or “frames”).
Example Camera System
[0022] FIG. **1** illustrates an embodiment of an example camera system **102**. The camera system **102** comprises an image sensor **104**, video storage **106**, and a processing unit **108**. Other optional components of the camera system **102** such as control interfaces, display screen, etc. are omitted from the figure for clarity of description. The image sensor **104** captures digital images or video. Because video comprises a sequence of images (or “frames”), description herein referring to images can be similarly applied to video and vice versa. Each captured image comprises a two-dimensional array of pixels. The captured frames depict a “scene,” which may include, for example, landscape, people, objects, etc represented by the captured pixels. Each pixel represents a depicted point in a scene captured in the digital video. Furthermore, each pixel is located at a pixel location, referring to, for example, (x,y) coordinates of the pixel within the frame. For example, a pixel may comprise {Red, Green, Blue} (RGB) values describing the relative intensities of the colors sensed by the image sensor **104** at a particular set of (x,y) coordinates in the frame. In various embodiments, the image sensor **104** may capture video suitable for providing output videos having high definition resolutions (for example, 4k resolution, 2k resolution, 1080p, 1080i, 960p, or 720p), standard definition resolutions, or other resolutions. The image sensor **104** may capture video at various frame rates such as, for example, 120 frames per seconds (FPS), 60 fps, 48, fps, or 30 fps, although other frame rates may also be used. Additionally, the image sensor **104** may include a lens that allows for wide-angle or ultra wide-angle video capture having fields of view of, for example, 90 degrees, 127 degrees, or 170 degrees, although other field of view angles may also be used.
[0023] Image frames captured by the image sensor **102** may be temporarily or permanently stored in the video storage **106** which may comprise, for example, a hard drive or a solid-state memory device (e.g., a memory card or universal serial bus (USB) memory device). The processing unit **108** processes images to convert between aspect ratios as will be described in further detail below. In one embodiment, the processing unit **108** comprises a processor **112** and a memory **114**. The memory **114** comprises a non-transitory computer-readable storage medium that stores computer-executable

program instructions for aspect ratio conversion, among other functions. To perform the aspect ratio conversion described herein, the processor **112** loads program instructions from the memory **114** and executes the instructions. Alternatively, the processing unit **108** could implement the aspect ratio conversion in hardware, firmware, or a combination of hardware, firmware, and/or software.

[0024] In one embodiment, the processing unit **108** converts between a source aspect ratio (i.e., the aspect ratio of the original images captured by the image sensor **104**) and a target aspect ratio (i.e., the aspect ratio of the image for storing or outputting by the camera system **102**). In one embodiment, the source aspect ratio makes full use of the available field of view of the image sensor **104** (remaining sensitive to mapping distortion effects). For example, in a camera system **102** having a 4:3 image sensor, the image sensor **104** captures the native content according to a 4:3 aspect ratio, although other source aspect ratios are also possible. The processing unit **108** then uses resolution compression and/or stretching in the appropriate axes to convert the captured images in the source aspect ratio to the target aspect ratio. In one embodiment, the conversion is achieved using a resolution remapping that applies a non-linear function across the image so as to minimize or reduce undesirable key feature aspect ratio distortions. Furthermore, in one embodiment, the aspect ratio conversion does not result in any loss of field of view.

[0025] In one embodiment, the aspect ratio conversion is performed by a warp module of the processing unit **108**. In addition to performing the aspect ratio conversion, the warp module may perform other functions such as, for example, reducing optical lens distortions such as typical barrel and pincushion distortions.

Aspect Ratio Conversion

[0026] Examples of techniques for aspect ratio conversion are discussed in further detail below. For the sake of clarity, the following description discusses examples involving conversions between a source aspect ratio of 4:3 and a target aspect ratio of 16:9. However, the described embodiments similarly apply to any source or target aspect ratios.

[0027] FIG. **2**A illustrates an example embodiment of a process for converting from a source aspect ratio to a target aspect ratio in a camera system. In the process of FIG. **2**A, an input image is obtained **202** in the source aspect ratio (e.g., a 4:3 aspect ratio). The image is then scaled **204** from the source aspect ratio (e.g., the 4:3 aspect ratio) to the target aspect ratio (e.g., a 16:9 aspect ratio) using a linear scaling function. A non-linear warping is then applied **206** to the scaled image. FIG. **2**B illustrates the process of FIG. **2**A as applied to an example image **212** containing an array of circles. As can be seen, the scaling function applied in step **204** causes the circles to be stretched horizontally and compressed vertically as shown in example image **214**. Because the scaling function applied in step **204** is linear, each circle is stretched/compressed equally independent of horizontal and vertical position. In the warping step **206**, a non-linear warping is applied which results in the circles being stretched/compressed by different amounts depending on their horizontal and vertical positions resulting in example image **216**.

[0028] As can also be observed from FIG. **2**B, the scaling and warping steps **204**, **206** preserves the full field of view in the resulting image **216** relative to the original image **212**. To achieve this, the warp module is configured so that some areas of the image are fully corrected geometrically, while some other areas are distorted. In the illustrated example, the center of the image is chosen to be the region of interest that is most fully corrected and the distortion increases in each direction as the frame boundary is approached. Thus, in image **216**, the center circle is fully corrected so that it maintains the original circular shape of the corresponding circle in the input image **212**. In the vertical direction, the circles become more distorted (e.g., more vertically compressed) in the as they approach the top and bottom edges. In the horizontal direction, the circles become more distorted (e.g., more horizontally stretched) as they approach the left and right edges. As a result, the circles in the corners exhibit the most distortion, because they have the highest amount of both vertical compression and horizontal stretching. In other embodiments, a different part of the image may be selected as the area most fully corrected, or in the case, of video, the area may dynamically change between images (e.g., to follow a moving object).

[0029] The distribution of distortion levels in different portions of the image may furthermore be tuned in one embodiment to control the size of objects as they pan from horizontally within a scene of video. Fully correcting the geometrical distortion in the center of the image would result in objects looking small in the center and very large on the sides. Thus, in the case of a video, an object may noticeably grow in size as it moves from the center to the edges of the display. In one embodiment, the warping function in step **206** is tuned to reduce this effect.

[0030] In an alternative embodiment, the scaling and warping functions applied in steps **204**, **206** could be performed in reverse order, such that the warping function in step **206** is applied first followed by scaling in step **204**. In another embodiment, the scaling and warping are combined into a single function such that only a single transformation is applied to the image that achieves both the scaling and warping. For example, in FIG. **2**B, image **212** may be converted directly to image **216** via a single function without producing the intermediate image **214**.

[0031] As will be apparent to those skilled in the art, an equitable horizontal remapping can be performed in manners similar to those described herein for vertical remapping if it is desired to decrease image width without decreasing horizontal image field of view and without creating undesirable key feature distortions. For example, images having a source aspect ratio of 2.39:1 may be converted to a 16:9 aspect ratio in this similar manner.

[0032] The scaling step (e.g., step **204** of FIG. **2**A) may be achieved either by scaling down one dimension (either the horizontal or vertical one, depending on the formats being converted) or scaling up the orthogonal direction. Scaling up has the benefit of preserving one dimension and only interpolates existing information to extend the other dimension, meaning all resolution is preserved. On the contrary, scaling down causes a loss of information.

[0033] FIG. **3** illustrates example images illustrating the aspect ratio conversion technique described herein. Image **302** illustrates an original image captured with a 4:3 aspect ratio. Image **304** illustrates a conventional cropping of the image to fit it to a 16:9 aspect ratio. As can be seen, the field of view is reduced with this technique and a portion of the image is lost. Image **306** illustrates the original image converted according to the techniques described herein. As can be seen, the aspect ratio conversion is achieved while maintaining the full field of view. Although some distortion may be introduced, the distortion is concentrated near the boundaries of the image (away from the center) and perceivable distortion is limited to an acceptable level.

[0034] FIG. **4** illustrates additional example images representing a checkerboard pattern, where image **502** represent an original 4:3 image, image **504** represents an image that has been cropped to achieve the 16:9 aspect ratio, and image **506** illustrates an image converted according to the techniques described herein. As can be seen, the perceivable distortion is small or zero near the center of image and increases somewhat at the edges and corners.

Examples of Warping Functions

[0035] In one embodiment, the warping function involves both a horizontal and vertical warping. For convenience of description, the horizontal and vertical warping is described as two steps, e.g., first horizontal then vertical. However, both horizontal and vertical warping can be executed in one step, for example, by applying a single transformation to the image. Furthermore, due to the symmetrical nature of the distortion, vertical and horizontal distortion profiles can be swapped.

[0036] An example of a horizontal warping function is illustrated in FIG. **5**. In this graph, the horizontal coordinate of a pixel is expressed as a percentage of the horizontal pixel position relative to the horizontal width of the image, where the percentage increases in a direction away from a reference edge. The vertical coordinate is similarly expressed. The amount of distortion is expressed in terms of the horizontal distortion offset ΔH that a point in the image moves in a direction away from the reference edge divided by the horizontal image size H. Since the warping function is horizontally symmetric in this embodiment, the reference edge can be either the right edge or the left edge. In this embodiment, the horizontal warp is function of the horizontal coordinate only and is independent of vertical position. The horizontal warp distortion stretches pixels horizontally in a manner that corrects for the “short and fat” effect introduced by 4:3 to 16:9 stretching, or similarly undesirable effects introduced by other aspect ratio conversions. In one embodiment of the horizontal warp, pixels along vertical edges are not offset (the offset value is zero) because there is no information beyond the edges and it may be undesirable to introduce padding (e.g., black vertical lines) on the sides of the image. The magnitude of the distortion is symmetric in one embodiment, with pixels on the left half of the image shifting to the right and pixels on the right half of the image shifting to the left to compensate for the horizontal stretching effect. Since the center receives the contributions of pixels from both sides, the center region of the image is corrected the most, while the geometry on the sides is distorted to a small extent. This degradation in image quality along the sides can be compensated for to some extent in the vertical warping, as will be discussed below.

[0037] In one embodiment, the amount of horizontal correction applied can be manually tuned to reduce perceivable distortion in the output image. For example, fully correcting the geometrical distortion in the center may cause the objects in the center to be much smaller than on the sides. Thus, in one embodiment, the amount of horizontal correction can be tuned in combination with the vertical correction in order to preserve the width of objects throughout the horizontal plane.

[0038] In one embodiment, a similarly shaped function is used for vertical warping. In another embodiment, the vertical warping function is modified so that the amount of compensation in the vertical direction also depends on horizontal position. FIG. **6** illustrates an example of a vertical warping function, where the amount of distortion is express in terms of the vertical distortion offset ΔV indicating an amount that a pixel moves in a vertical direction away from a reference edge (e.g., the top edge or the bottom edge) divided by the vertical image size V. In one embodiment, vertical warping is a function of both the horizontal and vertical coordinates.

[0039] As mentioned above, a goal of the vertical distortion is to further correct the geometry that was not already corrected by horizontal distortion. The image center could be fully corrected using the horizontal distortion only (with no vertical warping).

[0040] However, spreading the correction along both horizontal and vertical axis effectively improves the geometry of not only the center, but also the top, bottom, left and right image sides. The most distorted regions in this embodiment are the four image corners, but this distortion does not substantially reduce perceived image quality. Having residual distortion in the corners while correcting the rest in the image results in a much more natural-looking effect since key scene features are usually not framed in the corners. Examples of this effect can be visible, however, in FIG. **4**, where the squares in the corners are more rectangular (as opposed to square), and FIG. **3** where the diver's right flipper is somewhat stretched. However, as a good trade off for these corner distortions, it can be observed that the central rows of squares in FIG. **4** maintain a relatively consistent width throughout the image. Furthermore, the diver's body in FIG. **3** has proportions that are relatively preserved across the image width.

[0041] In one embodiment, tunable parameters can be controlled to adjust the vertical distortion along both horizontal and vertical directions, resulting in the 3D-wave in FIG. **6**. In one embodiment, pixels are not offset along the horizontal edges to avoid introducing horizontal padding (e.g., black bands along the edges).

[0042] In the description above, the horizontal and vertical distortions have been decoupled for the sake of clarity. However, both distortions could be implemented in a single step. Similarly, in the description above, the aspect ratio conversion (4:3 to 16:9 in this example) has been decoupled from warp distortion, but these could also be combined into a single step.

[0043] Example equations are provided below for implementing an example warping function applied in step **206** of FIG. **2**. Those of ordinary skill in the art will understand that variations of these equations may also be used, and other implementations may apply that result in functions having substantially similar characteristics.

[0044] As explained above, the horizontal warp distortion in one embodiment is a function of the horizontal position only. It can therefore be represented in terms of a horizontal coordinate h in an equation such as the example equation below, or an equation substantially similar to the equation below:

[00001] $h / H = 0.1107h^6 + 0.534h^5 - 1.7813h^4 + 1.3167h^3 - 0.0722h^2 - 0.1073h$

[0045] The vertical warp distortion, in one embodiment, is a function of both the horizontal and vertical positions. Therefore, the vertical warp distortion can be represented as a family of equations ΔV/V.sub.n, where “n” is the horizontal coordinate expressed as a percent of the total horizontal image size. Intermediate horizontal coordinates can be interpolated from the example equations given below, or equations substantially similar to these:

[00002]

$v / V_0 = -0.0749v^6 - 0.3167v^5 + 1.0939v^4 - 0.8113v^3 = 0.0408v^2 + 0.0678v \quad v / V_{10} = -0.0658v^6 - 0.2785v^5 + 0.9617v^4 - 0.7132v^3 + 0.0359v^2 + 0.0596$

[0046] The warp distortion described above may be used with cameras producing either rectilinear images (without distortion) or images affected by optical lens distortion characterized by the following equation:

[00003](FOV) = (21.904) * (IH) - (.6852) * (IH) ^ 2.

where FOV is the field of view and IH is image height. As will be apparent to those of ordinary skill in the art, the equations above may vary when used with lenses having different distortion characteristics.

[0047] As described above, the above equations can be combined with a scaling function to generate a transformation that performs both scaling and warping.

[0048] In alternative embodiments, different equations may be used to achieve similar distortion characteristics. As mentioned above, the symmetric nature of the distortion and the fact that it can be expressed as a percent of image coordinates allows swapping horizontal and vertical distortions. Thus, in an alternative embodiment, the equations above for the horizontal axis can instead by applied in the vertical direction and vice versa.

[0049] Furthermore, in other alternative embodiments, the equations may change dynamically in different frames of a video. For example, warping may be applied in a manner that reduces distortion applied to a particular object in motion across different frames of a video since the viewer is likely to focus attention on the object in motion.

[0050] Although the example embodiments described herein relate to conversion between a 4:3 aspect ratio and a 16:9 aspect ratio, other aspect ratios may be used for the target and source aspect ratios. For example, in alternative embodiments the source aspect ratio can comprise a 4:3 aspect ratio, a 16:9 aspect ratio, a 1.85:1 aspect ratio, a 2.39:1 aspect ratio, a 3:2 aspect ratio, a 5:3 aspect ratio, a 5:4 aspect ratio, a 1:1 aspect ratio or any other aspect ratio. Similarly, in alternative embodiments, the target aspect ratio can comprise a 4:3 aspect ratio, a 16:9 aspect ratio, a 1.85:1 aspect ratio, a 2.39:1 aspect ratio, a 3:2 aspect ratio, a 5:3 aspect ratio, a 5:4 aspect ratio, a 1:1 aspect ratio or any other aspect ratio.

Additional Configuration Considerations

[0051] Throughout this specification, some embodiments have used the expression “coupled” along with its derivatives. The term “coupled” as used herein is not necessarily limited to two or more elements being in direct physical or electrical contact. Rather, the term “coupled” may also encompass two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other, or are structured to provide a thermal conduction path between the elements.

[0052] Likewise, as used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of elements is not necessarily limited to only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus.

[0053] In addition, use of the “a” or “an” are employed to describe elements and components of the embodiments herein. This is done merely for convenience and to give a general sense of the invention. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

[0054] Finally, as used herein any reference to “one embodiment” or “an embodiment” means that a particular element, feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearances of the phrase “in one embodiment” in various places in the specification are not necessarily all referring to the same embodiment.

[0055] Upon reading this disclosure, those of skill in the art will appreciate still additional alternative structural and functional designs for a camera expansion module as disclosed from the principles herein. Thus, while particular embodiments and applications have been illustrated and described, it is to be understood that the disclosed embodiments are not limited to the precise construction and components disclosed herein. Various modifications, changes and variations, which will be apparent to those skilled in the art, may be made in the arrangement, operation and details of the method and apparatus disclosed herein without departing from the spirit and scope defined in the appended claims.

Claims

1. A camera, comprising: an image sensor configured to capture a video, the video including video frames having a source aspect ratio, the video frames including pixels located at input positions defined along a first axis and a second axis, the first axis perpendicular to the second axis; a display coupled to one or more physical processors; and the one or more physical processors configured to: obtain the video frames of the video captured by the image sensor of the camera; generate output video frames by applying a transformation to the video frames of the video captured by the image sensor of the camera, the output video frames having a target aspect ratio different than the source aspect ratio, the output video frames including the pixels located at output positions defined along the first axis and the second axis; and present the output video frames on the display; wherein: the transformation non-uniformly shifts the pixels from being located at the input positions in the video frames to the output positions in the output video frames based on (1) the input positions along the first axis, and (2) the input positions along the second axis, wherein a target portion of a given video frame includes a subset of the pixels and differences between the input positions and the output positions of the subset of the pixels within the target portion are less than differences between the input positions and the output positions of others of the pixels.
2. The camera of claim 1, wherein the video is captured through an ultra wide-angle lens.
3. The camera of claim 1, wherein the transformation applied by the one or more physical processors of the camera includes: a linear scaling to uniformly stretch or compress the video frames along the first axis; and non-linear warping to non-uniformly warp the video frames along the second axis.
4. The camera of claim 3, wherein the transformation applied by the one or more physical processors of the camera includes non-linear warping to non-uniformly warp the video frames along both the first and second axes.
5. The camera of claim 3, wherein the linear scaling applied by the one or more physical processors of the camera changes the source aspect ratio to the target aspect ratio.
6. The camera of claim 3, wherein the non-linear warping is represented by a multi-order polynomial function.
7. The camera of claim 1, wherein a portion of a given output video frame corresponding to the target portion of the given video frame does not include geometrical distortion, and the geometrical distortion increases towards boundary of the given output video frame.
8. The camera of claim 1, wherein the target portion of different ones of the video frames is dynamically determined by the one or more physical processors of the camera.
9. The camera of claim 1, wherein the target portion of the different ones of the video frames is determined by the one or more physical processors of the camera based on a location of an object within the different ones of the video frames.
10. The camera of claim 1, wherein the transformation applied by the one or more physical processors of the camera preserves full field of view of the video frames in the output video frames.
11. The camera of claim 1, wherein the source aspect ratio makes use of available height of the image sensor.
12. The camera of claim 1, wherein the transformation applied by the one or more physical processors of the camera changes optical lens distortion between the video frames and the video frames.
13. The camera of claim 12, wherein the optical lens distortion includes barrel distortion or pincushion distortion.
14. The camera of claim 1, wherein pixel shifting from the input positions to the output positions changes based on distances between the input positions of the pixels and a center of the target portion within the given video frame.
15. A method for transforming images, the method performed by a camera including an image sensor, a display, and one or more physical processors, the image sensor configured to capture a video, the video including video frames having a source aspect ratio, the video frames including pixels located at input positions defined along a first axis and a second axis, the first axis perpendicular to the second axis, the method comprising: obtaining, by the camera, the video frames of the video captured by the image sensor of the camera; generating, by the camera, output video frames by applying a transformation to the video frames of the video captured by the image sensor of the camera, the output video frames having a target aspect ratio different than the source aspect ratio, the output video frames including the pixels located at output positions defined along the first axis and the second axis; and presenting, by the camera, the output video frames on the display; wherein: the transformation non-uniformly shifts the pixels from being located at the input positions in the video frames to the output positions in the output video frames based on (1) the input positions along the first axis, and (2) the input positions along the second axis, wherein a target portion of a given video frame includes a subset of the pixels and differences between the input positions and the output positions of the subset of the pixels within the target portion are less than differences between the input positions and the output positions of others of the pixels.
16. The method of claim 15, wherein the video is captured through an ultra wide-angle lens.
17. The method of claim 15, wherein the transformation applied by the camera includes: a linear scaling to uniformly stretch or compress the video frames along the first axis; and non-linear warping to non-uniformly warp the video frames along the second axis.
18. The method of claim 17, wherein the transformation applied by the camera includes non-linear warping to non-uniformly warp the video frames along both the first and second axes.
19. The method of claim 17, wherein the linear scaling applied by the camera changes the source aspect ratio to the target aspect ratio.
20. The method of claim 17, wherein the non-linear warping is represented by a multi-order polynomial function.
21. The method of claim 15, wherein a portion of a given output video frame corresponding to the target portion of the given video frame does not include geometrical distortion, and the geometrical distortion increases towards boundary of the given output video frame.
22. The method of claim 15, wherein the target portion of different ones of the video frames is dynamically determined by the camera.
23. The method of claim 15, wherein the target portion of the different ones of the video frames is determined by the camera based on a location of an object within the different ones of the video frames.
24. The method of claim 15, wherein the transformation applied by the camera preserves full field of view of the video frames in the output video frames.
25. The method of claim 15, wherein the source aspect ratio makes use of available height of the image sensor.
26. The method of claim 15, wherein the transformation applied by the camera changes optical lens distortion between the video frames and the video frames.
27. The method of claim 26, wherein the optical lens distortion includes barrel distortion or pincushion distortion.
28. The method of claim 15, wherein pixel shifting from the input positions to the output positions changes based on distances between the input positions of the pixels and a center of the target portion within the given video frame.