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Active alignment method to dual balance camera spatial frequency response

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ABSTRACT

In camera manufacturing, an active alignment process is used to align the optical axis of the lens with the sensor axis of the camera. The active alignment process reduces the spatial frequency response (SFR) corner-to-corner imbalance that causes SFR differences at image corners. The active alignment process is typically carried out with the object at the infinity position with respect to the lens. As a result, in auto-focus cameras with movable lenses, higher SFR corner-to-corner imbalance persists in macro positions. The techniques of this disclosure involve applying the active alignment process at infinity and at macro positions to distribute SFR corner-to-corner imbalance between the two positions.

KEYWORDS

- Spatial Frequency Response (SFR)
- Corner-to-corner imbalance
- Lens optical axis
- Camera sensor axis
- Active alignment
- Movable relay lens
- SFR test chart

BACKGROUND

In camera manufacturing, an active alignment process is used to align the optical axis of the lens with the sensor axis of the camera. The active alignment process reduces the spatial frequency response (SFR) corner-to-corner imbalance that causes SFR differences at image corners. The active alignment process is typically carried out with the object at the infinity position with respect to the lens. A typical active alignment machine includes an SFR test chart, a relay lens placed between the SFR test chart and the camera lens to project the SFR test chart image at the infinite position, a holder to secure the Voice Coil Motor (VCM) or unibody camera barrel, and a multi-degree sensor platform that holds and aligns the camera sensor axis in relation to the optical axis of the camera lens. Such a setup can align the optical axis of the camera lens and the sensor axis of the camera only at the infinity position of the object.

At the end of the process, the lens placement in relation to the camera sensor achieves the best possible SFR corner-to-corner balance. The process is ideally suited for fixed focus cameras, especially those with unibody design, in which the lens does not need to move. However, in auto-focus cameras with movable lenses, owing to the moving tilt intrinsic to the VCM used for lens movement, higher SFR corner-to-corner imbalance persists in positions in which the objects are not at the position at which the active alignment process was applied. As a result, when active alignment process is carried out with the object at the infinity position, cameras with movable lenses continue to exhibit higher SFR corner-to-corner imbalance for objects at macro positions compared to objects at infinity.

DESCRIPTION

The techniques of this disclosure involve modifying the typical active alignment process such that it can be applied at two different positions of the object: infinity and macro. Carrying out the alignment at the two different positions of the object is achieved by using an adjustable SFR test chart and a movable relay lens placed between the SFR test chart and the camera lens. By appropriately adjusting the SFR test chart and moving the relay lens, the active alignment process can be applied at infinity as well as macro position of the object.

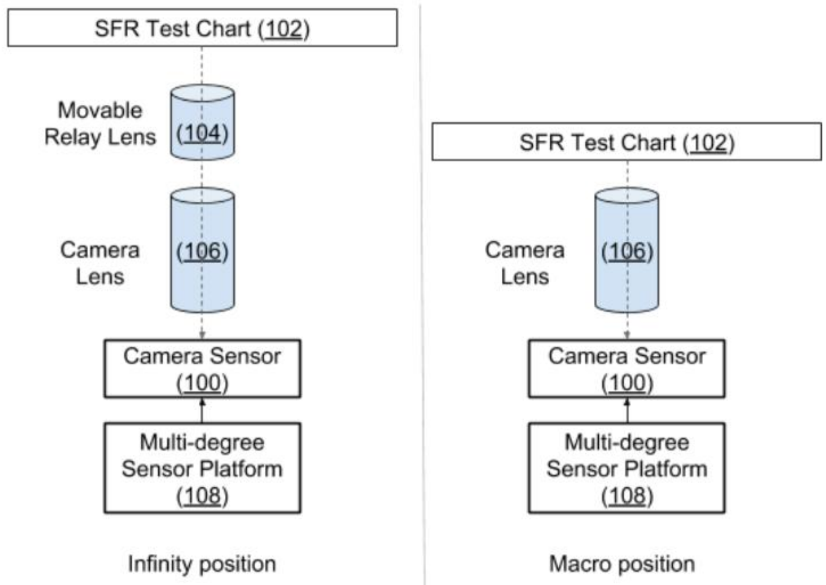

Fig. 1: Active alignment process with adjustable SFR and movable relay lens

Fig. 1 shows an operational realization of the techniques of this disclosure. In the first stage shown on the left in Fig. 1, the active alignment process is carried out with the object at the infinity position. In this case, the adjustable SFR test chart (102) is placed at a position where an image is projected at infinity in relation to the camera sensor (100) by the relay lens (104) placed between the SFR test chart and the camera lens (106). The multi-degree sensor platform (108) is then moved such that the SFR corner-to-corner imbalance is minimized with the object at the infinity position. At the end of this stage of the alignment process, the optical axis of the camera lens is very close to the sensor axis.

In the second stage of the process, shown on the right in Fig. 1, the movable relay lens is moved away, and the adjustable SFR test chart is placed in a position that corresponds to the macro position of the camera lens. The movable camera lens is moved to the macro position as well. The active alignment process is then repeated at the macro position by moving the multi-degree sensor platform such that the SFR corner-to-corner imbalance is minimized with the object at the macro position.

Owing to the intrinsic moving tilt of the VCM, the direction of the sensor axis after the second stage of active alignment is different from that at the end of the first stage. At the end, the multi-degree sensor platform is moved such that the final adjusted direction of the sensor axis in relation to the optical axis of the camera lens is the vector sum of the sensor axis directions at the ends of the first and the second stages of the active alignment process carried out using the techniques of this disclosure. As a result, the overall SFR corner-to-corner balance adjustment is distributed between the infinity and macro positions of the object rather than being applied to only one position.

The quality of a camera is rated by various standards and benchmarks, such as the DxO score typical for rating cameras in mobile phones. The ratings include evaluation of SFR corner-to-corner balance at various lens positions. The techniques of this disclosure improve the SFR corner-to-corner balance at the infinity as well as macro positions of the camera lens, thus enabling the camera to achieve higher scores on ratings such as DxO.

The described techniques can be used for both single auto-focus and dual auto-focus cameras. The techniques can be incorporated in camera active alignment machines.

CONCLUSION

The active alignment process used to align the optical axis of the lens with the sensor axis of the camera reduces the spatial frequency response (SFR) corner-to-corner imbalance that causes SFR differences at image corners. The active alignment process is typically carried out with the object at the infinity position with respect to the lens. As a result, in auto-focus cameras with movable lenses, higher SFR corner-to-corner imbalance persists in macro positions. The techniques of this disclosure involve utilizing an adjustable SFR test chart with a movable relay lens to apply the active alignment process at infinity and macro positions. The final adjusted direction of the sensor axis in relation to the optical axis of the camera lens is the vector sum of the sensor axis directions adjusted for the infinity and macro position, respectively. As a result, the overall SFR corner-to-corner balance adjustment is distributed between the infinity and macro positions of the object rather than being applied to only one position.