US 20060285080A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2006/0285080 A1

KURIHARA (43) Pub. Date: Dec. 21, 2006

(54) PROJECTOR AND PROJECTION METHOD

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(21) Appl. No.: **11/423,940**

(22) Filed: **Jun. 13, 2006**

(30) **Foreign Application Priority Data**

Jun. 16, 2005 (JP) 2005-176026

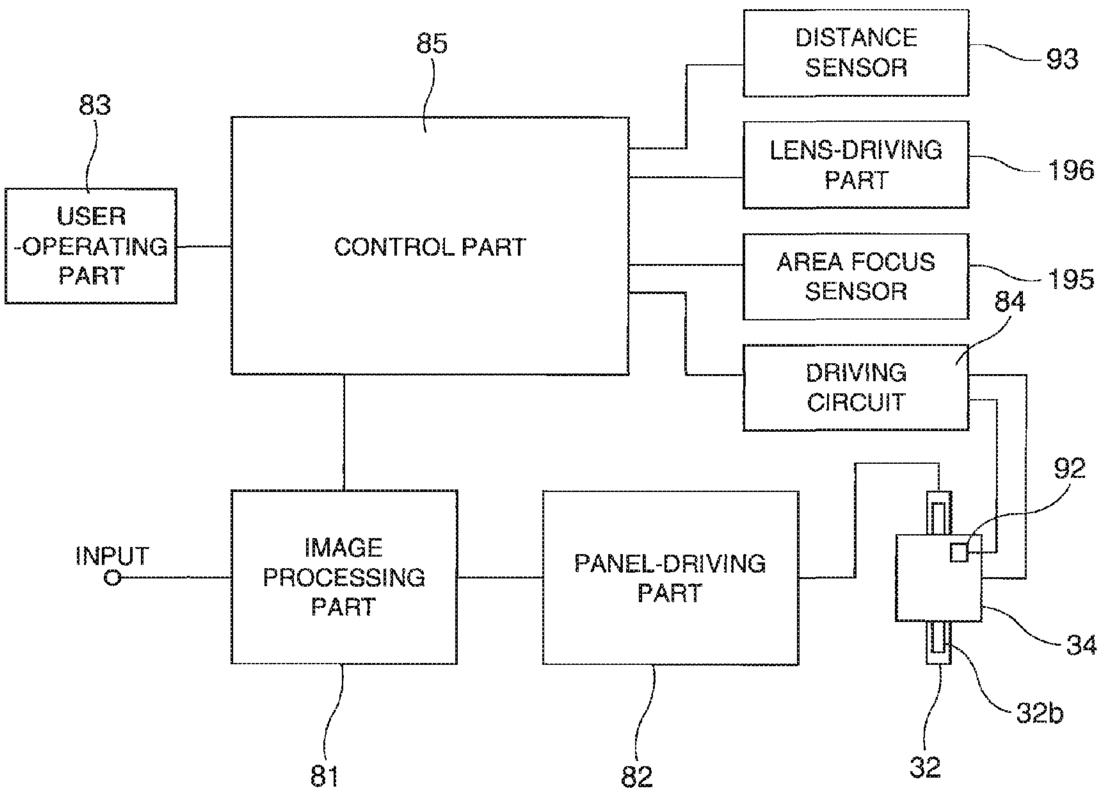
Publication Classification

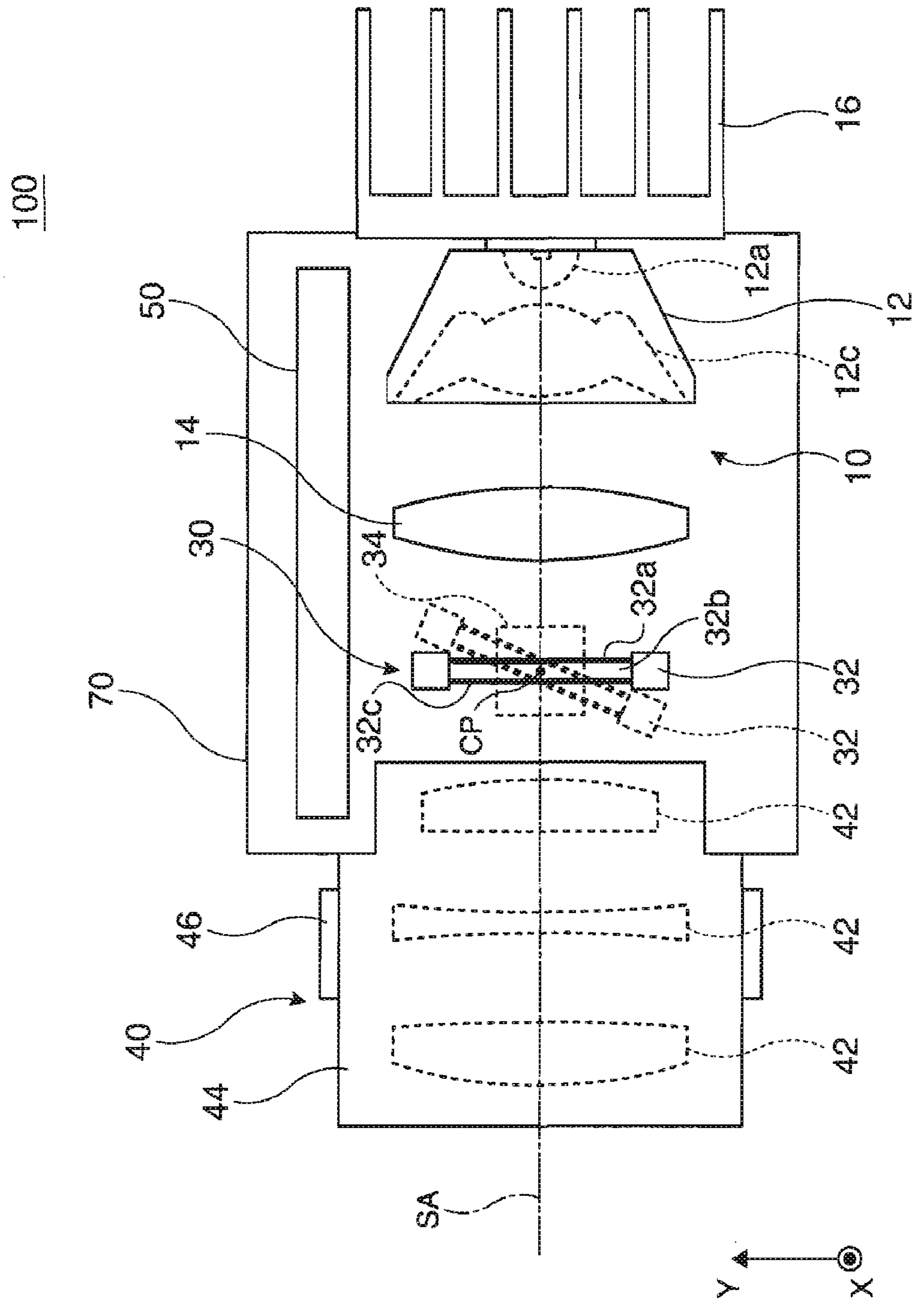
(51) **Int. Cl.**
G03B 21/14 (2006.01)

(52) **U.S. Cl.** **353/70**

(57) **ABSTRACT**

A projector includes: a light-modulation device for modulating an illumination light according to a piece of image information; a projection optical system for protecting a modulated light resulting from the modulation by the light-modulation device as an image on a screen; a movable holder capable of holding the light-modulation device in a condition where the light-modulation device is tilted with respect to an optical axis; and a control-processing device which corrects a projected image formed in the light-modulation device based on a distance from the projection optical system to the screen and a tilt angle of the light-modulation device thereby to correct a trapezoidal distortion of an image projected on the screen when the light-modulation device is arranged in relation to the projection optical system and the screen so that a requirement of Scheimpflug rule is satisfied.




100
16
50
12a
12
12c
14
10
30
34
32a
32b
32
70
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CP
32
42
42
46
40
42
44
SA
Y
X

FIG. 1

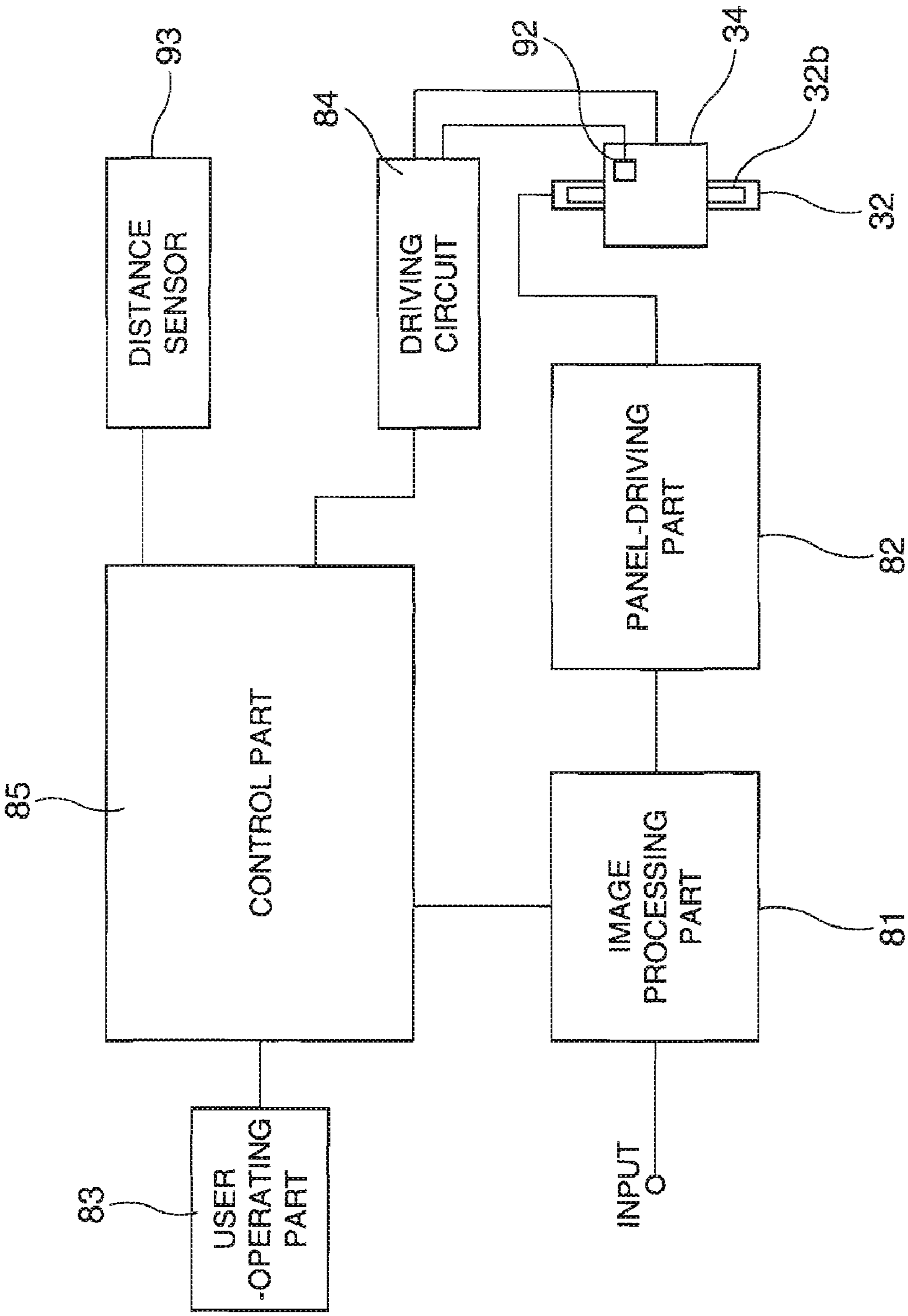
93
DISTANCE SENSOR
84
DRIVING CIRCUIT
92
34
32b
32
PANEL-DRIVING PART
82
85
CONTROL PART
IMAGE PROCESSING PART
81
83
USER -OPERATING PART
INPUT

FIG. 2

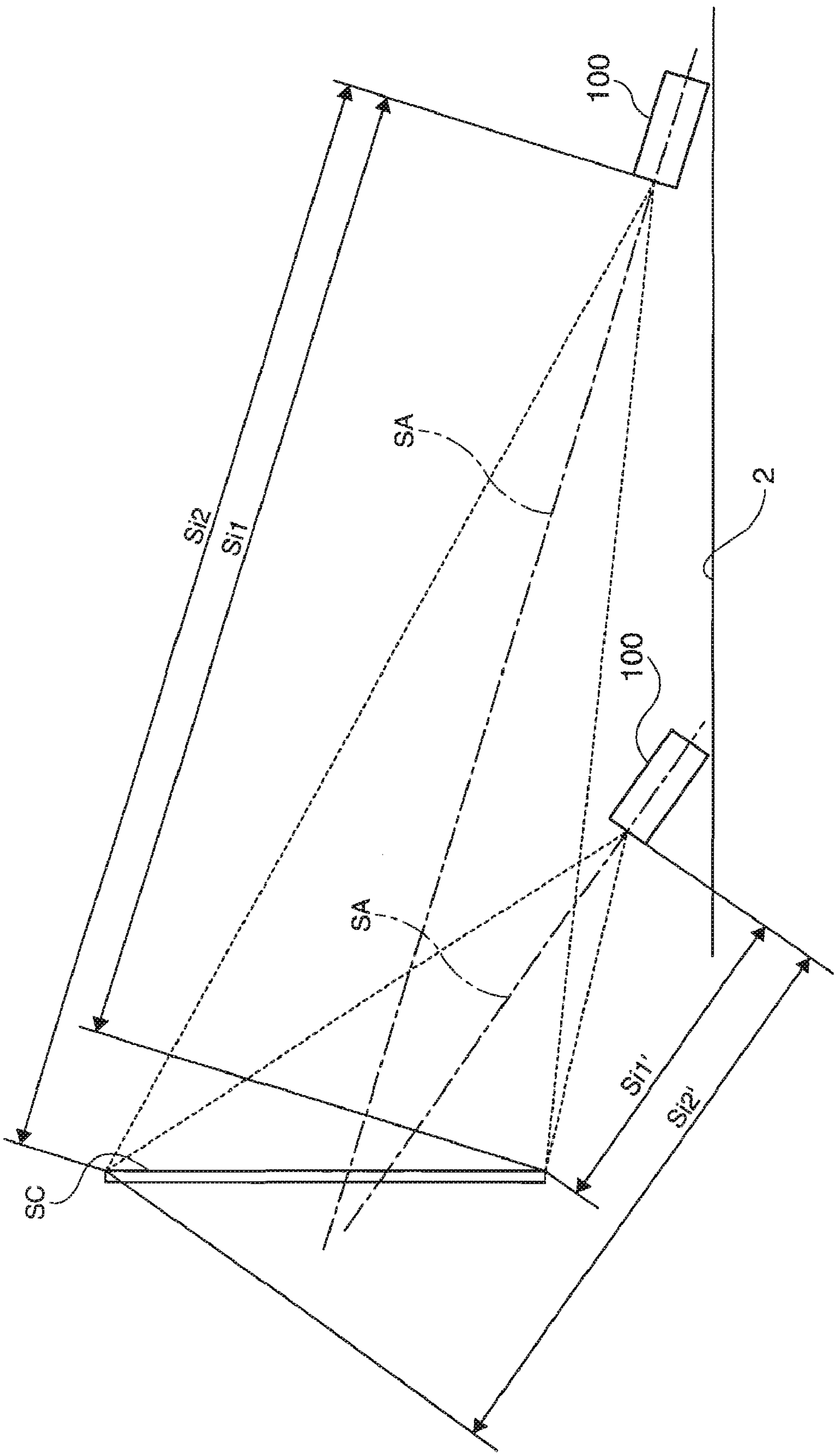

FIG. 3

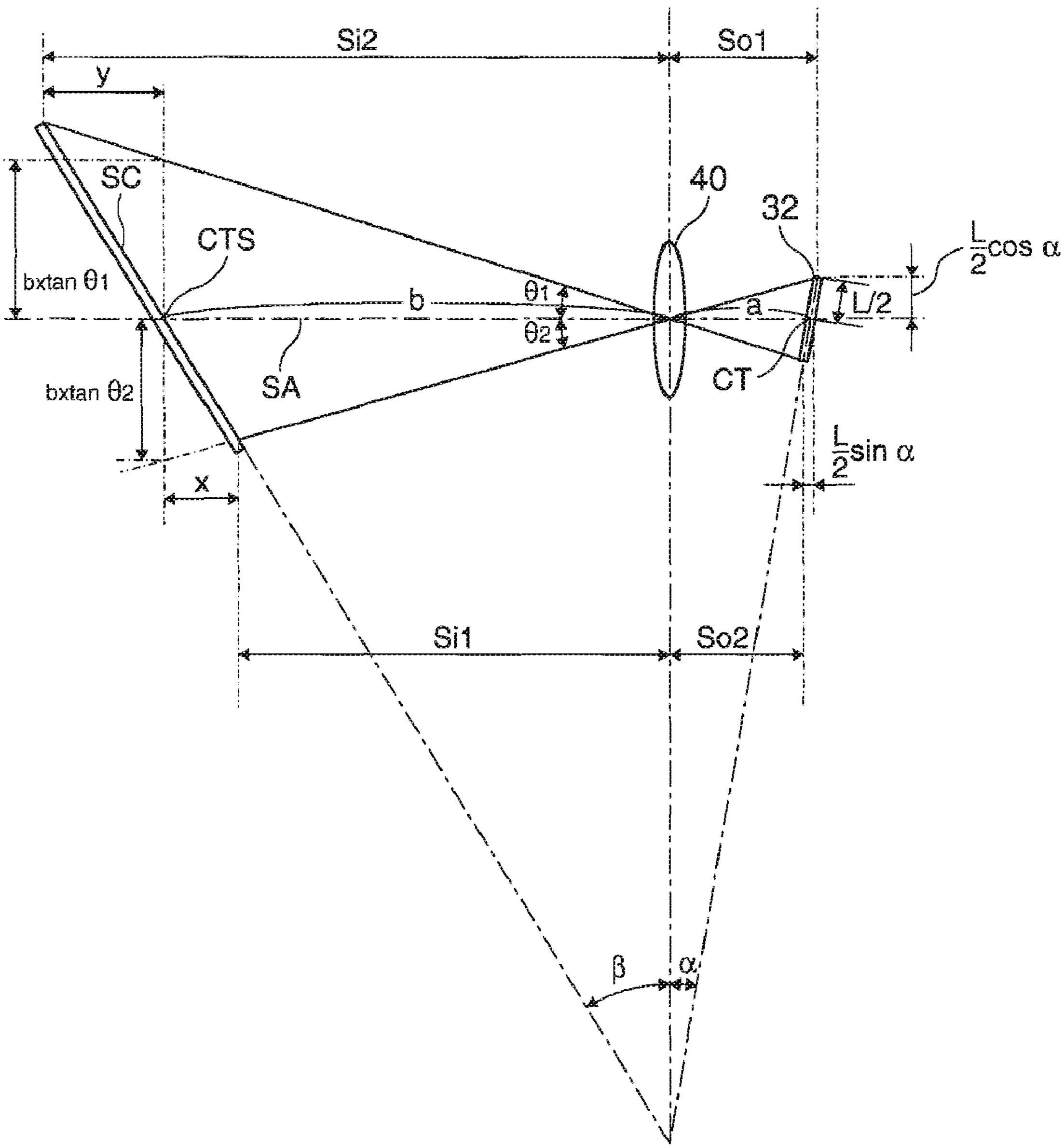
Si2
So1
y
SC
40
32
CTS
bxtan θ1
b
θ1
a
L/2
θ2
SA
CT
bxtan θ2
x
Si1
So2
β
α

FIG. 4

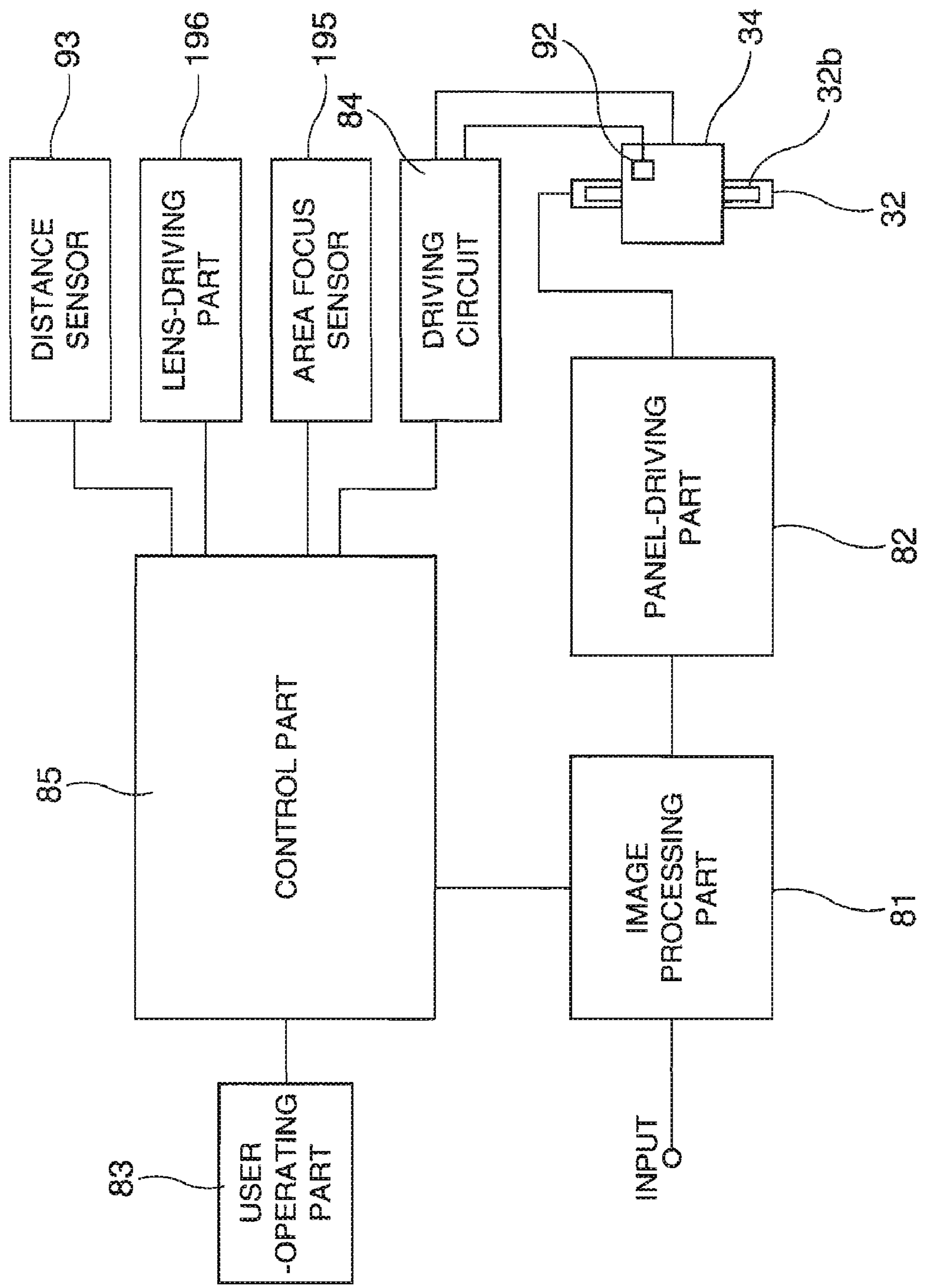
93
196
195
84
92
34
32b
32
DISTANCE SENSOR
LENS-DRIVING PART
AREA FOCUS SENSOR
DRIVING CIRCUIT
85
CONTROL PART
PANEL-DRIVING PART
82
IMAGE PROCESSING PART
81
83
USER -OPERATING PART
INPUT

FIG. 5

PROJECTOR AND PROJECTION METHOD

BACKGROUND

[0001] 1. Technical Field

[0002] The present invention relates to a projector which uses a liquid crystal display panel or some other light-modulation device to project a video image, and a projection method using the same.

[0003] 2. Related Art

[0004] A projector is typically placed on a desk, and used to project an image on a screen vertically placed above the desk. In this case, the projector body is placed horizontally, and oblique projection is performed by lens shift to prevent trapezoidal distortion, focus blurring, etc.

[0005] However, in the case of using means of lens shift, the optical system of the projector is arranged so that the optical axis of a light valve thereof is displaced from the optical axis of a projection lens thereof. Hence, in order to achieve brightness equivalent to brightness in the case without doing the lens shift, it is necessary to make the diameter of the projection lens into sufficient size, which tends to increase the size of the projector body and a manufacturing cost thereof. The above tendency is remarkable particularly in the application where the projection length is made shorter and the application where the projector is placed in a place far below the screen.

[0006] Therefore, with a compact desktop projector and other projectors assumed to be used in the situation where the projection length is made shorter or the situation where the projector is placed at a position far below the screen, it has been common that "Tilt projection," in which the projector body is tilted, is performed, and the trapezoidal distortion caused during this time is corrected by digital image processing (see JP-A-2003-283963 and JP-A-2003-78842).

[0007] Further, another projector includes: a first projection optical system which forms an intermediate image with a trapezoidal distortion; and a second projection optical system which removes the trapezoidal distortion of the intermediate image, and it is arranged so that moving lens elements included in the second projection optical system in a direction of the optical axis or changing an angle thereof enables focusing on anywhere on the whole plane of a projection screen and therefore it can prevent the occurrence of trapezoidal distortion (see JP-A-6-148566).

[0008] However, with a projector as described in the former case on the assumption that tilt projection is performed, making the projection length shorter or tilting the projector body greatly enlarges the difference in projection length between up and down side of an image plane. Thus, though a large depth of focus is required for a projection lens on one hand, the view angle has to be widened on the other hand. Therefore, it is difficult to obtain a projection lens which can meet both the requirements.

[0009] Further, with a projector as described in the latter case, it is required to move lens elements included in the projection lens in a direction of the optical axis or to change an angle thereof. This not only makes the projection lens or driving mechanism thereof larger but also makes the control mechanism more complicated, leading to an increase in the cost of the projector.

SUMMARY

[0010] An advantage of some aspects of the invention is to provide a projector with a relatively compact and low-cost projection lens, which enables focusing on an entire surface of a projection screen and which can prevent the occurrence of trapezoidal distortion, and a protection method using the projector.

[0011] A projector of an aspect of the invention includes: (a) a light-modulation device for modulating an illumination light according to a piece of image information; (b) a projection optical system or projecting a modulated light resulting from the modulation by the light-modulation device as an image on a screen; (c) a movable holder capable of holding the light-modulation device in a condition where the light-modulation device is tilted with respect to an optical axis; and (d) a control-processing device which corrects a trapezoidal distortion of an image projected on the screen by correcting an image formed in the light-modulation device based on a distance from the projection optical system to the screen and a tilt angle of the light-modulation, device, when the light-modulation device is arranged in satisfying a requirement of Scheimflug rule to the projection optical system and the screen.

[0012] In the projector, the movable holder can hold the light-modulation device in a condition where the light-modulation device is tilted with respect to the optical axis and as such, the light-modulation device can be arranged in satisfying the requirement of Scheimpflug rule to the projection optical system and the screen. Therefore, an image projected on the screen can be focused on the respective locations on the screen. Further, in the case where the requirement of Scheimpflug rule is satisfied, the control-processing device carries out trapezoidal distortion of an image projected on the screen based on the distance from the projection optical system to the screen and the tilt angle of the light-modulation device and as such, the whole projection image can be focused and made sharper without using a particular projection optical system, and the occurrence of trapezoidal distortion of the projection image can be suppressed.

[0013] Also, according to a specific form in association to the invention or an aspect thereof, the projection optical system has a focusing ring for focus adjustment, and the control-processing device determines the distance to the screen based on an output from a distance sensor for detecting a piece of distance information concerning the focusing ring. In this case, the distance to the screen can be obtained somewhat precisely and readily. Consequently, an image with a little trapezoidal distortion can be projected somewhat easily.

[0014] In addition, according to another aspect of the invention, the projector further includes a tilt sensor for detecting a piece of information on the tilt angle of the light-modulation device, wherein the control-processing device gains a piece of information on a tilt condition of the screen with respect to the optical axis based on outputs from the tilt sensor and the distance sensor. In this case, the trapezoidal distortion of a projection image can be corrected based on a piece of information concerning the tilt condition of the screen with reliability.

[0015] Further, according to another aspect of the invention, the movable holder forces the light-modulation device to rotate around a center position thereof where the optical axis goes through the light-modulation device, and the control-processing device writes a piece of information for checking a focusing condition in the center position of the light-modulation device or in a nearby position thereof when adjusting a tilting amount of the light-modulation device. In this case, the projection image of the piece of information is projected on the screen and as such, and an image can be focused on the center position on the optical axis with reference to a projection image for checking a focusing condition like this, and the light-modulation device can be made to rotate while maintaining the in-focus condition in the center position on the optical axis. As a result, a whole projection image can be focused rapidly.

[0016] The projection method according to another aspect of the invention is a projection method, by which a light-modulation device modulates an illumination light according to a piece of image information thereby to attain a modulated light, and the modulated light is projected, as an image, on a screen by a projection optical system. The projection method includes the steps of: (a) arranging the light-modulation device in satisfying a requirement of Scheimpflug rule to the projection optical system and the screen, by holding the light-modulation device so as to form a predetermined tilt angle with respect to an optical axis; and (b) correcting a trapezoidal distortion of an image projected on the screen, by correcting an image formed in the light-modulation device based on a distance from the projection optical system to the screen and the tilt angle of the light-modulation device. The predetermined tilt angle here includes a no-tilt condition such that a normal line of the light-modulation device is in parallel with the optical axis. (i.e. the tilt angle is zero).

[0017] According to the above-described projection method, the light-modulation device can be arranged in satisfying the requirement of Scheimpflug rule to the projection optical system and the screen and as such, an image projected on the screen can be focused on the respective locations on the screen. Further, in the case where the requirement of Scheimpflug rule is satisfied, the trapezoidal distortion of an image projected on the screen is corrected based on the distance from the projection optical system to the screen and the tilt angle of the light-modulation device and as such, a projection image can be focused generally and easily without using a particular projection optical system and the occurrence of trapezoidal distortion of the projection image can be suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The invention will be described with reference to the accompanying drawings, wherein like numbers reference like elements.

[0019] **FIG. 1** is a view of assistance in explaining a projector in association with the first embodiment.

[0020] **FIG. 2** is a block diagram of assistance in explaining a circuit and the like built in the projector shown in **FIG. 1**.

[0021] **FIG. 3** is a view of assistance in explaining how to use the projector shown in **FIG. 1**.

[0022] **FIG. 4** is a view of assistance in schematically explaining the magnification of projection for the projector shown in **FIG. 1**.

[0023] **FIG. 5** is a block diagram of assistance in partially explaining a projector in association with the second embodiment.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

First Embodiment

[0024] **FIG. 1** is a exploded perspective view of assistance in explaining a structure of a projector in association with the first embodiment. The projector **100** in the embodiment includes: an illuminating device **10**; a light-modulation device **30**; a projection optical system **40**; and a circuit unit **50**. Of these constituents, optical elements constituting the illuminating device **10**, the light-modulation device **30** and the projection optical system **40** respectively are positioned and housed in a housing part **70**, which is a housing for optical parts and for which a predetermined system optical axis SA is set.

[0025] The illuminating device **10** is fixed so that it is embedded in the rectangular parallelepiped housing part **70**, and includes: an illuminating unit **12** including a light-emitting source; an extension lens **14** for beam shaping; and a cooling fin **16** as a heat-dissipating device. Of these constituents, the illuminating unit **12** has: an LED light source **12***a* which creates a source light with an amount of light enough to meet the need for image light formation; and a light-uniformizing element **12***c* which uniformizes source light within the cross section of flux of light thereby to form an illumination light for the light-modulation device **30**. The extension lens **14** is housed in the housing part **70** and fixed by a certain means (not shown). The extension lens **14** performs optical extension of the cross sectional shape of a beam of illumination light thereby to illuminate an illumination-target region of the light-modulation device **30** with efficiency. The cooling fin **16** performs air cooling thereby to dissipate the heat generated when source light is created in the illuminating unit **12**.

[0026] The light-modulation device **30** is housed by and fixed in the housing part **70**. The light-modulation device includes a liquid crystal light valve **32** and a rotation-driving device **34**. The liquid crystal light valve **32** is a color-display, single-panel type light-modulation device. The liquid crystal light valve **32** uses a built-in polarizer **32***a* to restrict the direction of polarization of illumination light launched into it to a narrower range, and enhances the degree of polarization. Further, the liquid crystal light valve **32** regulates the condition of polarization of illumination light on a pixel-by-pixel basis according to a drive signal or image signal input to the built-in liquid crystal display panel **32***b* thereby to form a modulated light from the illumination light with its polarization degree enhanced by the above-described polarizer **32***a*. Still further, the liquid crystal light valve **32** has a built-in polarizer **32***c*, in which a polarization component In a particular direction is selected out of the modulated light obtained in the liquid crystal display panel **32***b* thereby to form image light.

[0027] The liquid crystal light valve **32** is supported by the rotation-driving device **34**, and arranged so that it can rotate about e.g. X-axis extending perpendicularly to the system optical axis SA using the center position CT of its image-forming region as a fulcrum. The rotation-driving device **34**

can hold the liquid crystal light valve **32** tilting the light valve by a desired angle with respect to the optical axis, which is to be described later. In other words, a normal line of the liquid crystal light valve **32** can be set to form a desired angle (including 0°) with respect to the optical axis. In this case, a tilt sensor (not shown) is used to monitor the tilt angle of the liquid crystal light valve **32**.

[**0028**] The projection optical system **40** includes two or more lenses **42**, and is partially housed and fixed in the housing part **70** by a lens barrel **44**. The projection optical system **40** projects, as projected light, image light formed by the light-modulation device **30** onto a screen (not shown) with an appropriate magnification. Around the external circumference of the lens barrel **44** of the projection optical system **40**, a focusing ring **46** is provided, which can be made to rotate along the side face of the lens barrel **44**. When the focusing ring **46** is made to rotate appropriately, the one or more of the lenses **42** can be moved in the direction of the optical axis, whereby a focusing condition of an image projected on the screen can be adjusted. The focusing ring **46** has a distance sensor for detecting the amount of the rotation knot shown). Based on the output from the distance sensor, the distance from the projection optical system **40** to the screen can be detected as a piece of distance information.

[**0029**] The circuit unit **50** is intended to supply electric power to the illuminating device **10** and regulate the working condition of the light-modulation device **30**. The circuit unit **50** includes a circuit board with a circuit pattern for wiring on a surface thereof, an IC mounted on the circuit board, and other electronic parts.

[**0030**] **FIG. 2** is a block diagram of assistance in partially conceptualizing a circuit device built in the projector **100** shown in **FIG. 1**.

[**0031**] The circuit device includes: an image processing part **81** to which an external image signal such as a video signal is input; a panel-driving part **82** For driving the liquid crystal display panel **32***b* (also shown in **FIG. 1**); a user-operating part **83** which a user operates when the user enters his or her direction; a driving circuit **84** for forcing the rotation-driving device **34** (also shown in **FIG. 1** to work; and a control part **85** for comprehensively controlling the operations of these constituents. In addition, the circuit device includes: a tilt sensor **92** for detecting a tilt angle of the liquid crystal light valve **32**; and a distance sensor **93** for detecting a rotating position of the focusing ring **46** (shown **FIG. 1**). Of the these constituents, e.g. the image processing part **81**, the panel-driving part **82**, the driving circuit **84** and the control part **85** are incorporated in the circuit unit **50** (shown in **FIG. 1**)

[**0032**] The image processing part **81** is capable of correcting an image to be projected on a screen in its size and distortion or color balance thereof by carrying out an appropriate process on an image signal input from the outside thereof. Also, the image processing part **81** works based on a direction signal from the control part **35**. For example, the image processing part **81** writes an image pattern (an image to be projected) resulting from trapezoidal transformation into an appropriate area in the image-forming region of the liquid crystal display panel **32***b* through the panel-driving part **82**. Thus, even when the screen is inclined with respect to the projection optical system **40**, an image with no distortion can be projected on a rectangular region on the screen. Also, the image processing part **81** is capable of projecting, as an image, additional information including a symbol and a character onto a screen instead of an image signal or superposing the additional information on the image signal. In other words, the image processing part **81** works based on a direction signal from the control part **85**, and it performs, for example, an appropriate write operation on the liquid crystal display panel **32***b* through the panel-driving part **82** to display an operation setting and confirmatory menu of the projector **100**, and various kinds of information concerning a working condition, etc. on a screen, and writes a focus mark for checking a focusing condition (a piece of information to be projected) in the center position CT of the liquid crystal display panel **32***b* or in a nearby position thereof to project a corresponding mark for checking a focusing condition onto the screen. The mark is utilized when the focusing ring **46** is used for focusing of the projection optical system **40**.

[**0033**] The panel-driving part **82** generates a drive signal for adjusting the working condition of the liquid crystal display panel **32***b* based on an image signal processed in and output from the Image processing part **81**. Thus, a desired video or picture image can be formed as a distribution of transmissivity corresponding to an image signal, etc. Input from the image processing part **81** in the liquid crystal light valve **32** which includes the liquid crystal display panel **32***b* and the polarizers **32***a*, **32***c* attached thereto.

[**0034**] The driving circuit **84** is capable of appropriately increasing and decreasing the tilt angle of the liquid crystal light valve **32** by outputting a control signal to the rotation-driving device **34**. In addition, the driving circuit **84** monitors the tilt angle of the liquid crystal light valve **32** based on a detected signal from the tilt sensor **92** incorporated in the rotation-driving device **34**.

[**0035**] The control part **85** is intended to comprehensively control operations of the projector **100**. The control part regulates an image to be displayed on the liquid crystal display panel **32***b* through the image processing part **81**. Also, the control part **85** can force the rotation-driving device **34** to work appropriately based on a direction from the user-operating part **83**, and set the tilting posture of the liquid crystal light valve **32** so that the requirement of Scheimpflug rule is satisfied. In this case the tilt angle of the liquid crystal light valve **32** can be detected by the tilt sensor **92**. Further, the control part **85** monitors the rotating position of the focusing ring **46** through the distance sensor **93** at all times, and therefore it is possible to detect the distance from the projection optical system **40** to the screen. That is, in the case where a user operates the focusing ring **46** to focus on an intersection point region thereof with the system optical axis SA on the screen, the distance from the projection optical system **40** to the intersection point region on the screen is calculated.

[**0036**] **FIG. 3** is a view of assistance in explaining how to use the projector **100** in this embodiment. It is clear from the drawing that in the case of carrying out the projection onto a screen SC with the projector **100** placed on a stand **2**, when the elevation angle of the projector **100** is small, the difference between the distance Si**1** from the projector to the lower edge of the screen SC and the distance Si**2** from the projector to the upper edge thereof is small, and therefore the required depth of focus is small. In contrast, it is obvious that when the elevation angle of the projector **100** is large, the difference between the distance Si**1**' from the projector to the lower edge of the screen SC and the distance Si**2**' from the projector to the upper edge of the screen SC is large, and therefore the required depth of focus is large. In other words, as for the projector **100** used under the condition where the elevation angle is large, it is difficult to use only the projection optical system **40** to increase the depth of focus. Therefore, it is desired that the projection optical system **40** and the liquid crystal light valve **32** of the projector **100** are arranged in relation to the screen SC so that the requirement of Scheimpflug rule is satisfied (the image-forming plane of the liquid crystal light valve **32**, which is a subject, the lens principal plane of the projection optical system **40** and a plane of the screen SC as an image plane intersect in one place). When such requirement of Scheimpflug rule is satisfied, a projection image can be focused on an upper and lower portion of the screen SC regardless of the size of the depth of focus of the projection optical system **40**.

[0037] **FIG. 4** is a view of assistance in schematically explaining the setting of the magnification of projection for the projector **100** in this embodiment. In the case of the projector **100**, it is assumed that the requirement of Scheimpflug rule is satisfied in the relation between the projection optical system **40** and the screen SC by tilting the liquid crystal light valve **32** by the tilt angle α. Now, it is note that the tilt angle α has been known as a measured value of the tilt by the tilt sensor **92**.

[0038] In the drawing, the angle β represents a tilt angle of the screen SC; the angle θ**1** represents a divergence angle of the projection optical system **40** to the upper edge of the screen SC; the angle θ**2** represents a divergence angle of the projection optical system **40** to the lower edge of the screen SC. Further, the symbol a represents the distance from the principal point (principal plane) of the projection optical system **40** to the center position CT of the liquid crystal light valve **32**; the symbol b represents the distance from the principal point (principal plane) of the projection optical system **40** to the screen SC along the system optical axis SA. Of the symbols, the distance a is a known value which is determined when the projector **100** is designed. The distance b has been known from the conversion from a measured value obtained by the distance sensor **93**. In addition, the symbol Si**1** represents the distance from the principal point of the protection optical system **40** to the lower edge of the screen SC; the symbol Si**2** represents the distance from the principal point of the projection optical system **40** to the upper edge of the screen SC; the symbol So**1** represents the distance from the principal point of the projection optical system **40** to the upper edge of the liquid crystal light valve **32**; and the symbol So**2** represents the distance from the principal point of the projection optical system **40** to the lower edge of the liquid crystal light valve **32**.

[0039] In this case, the magnification of projection M**1** in the lower edge of an image projected on the screen and the magnification of projection M**2** in the upper edge of the image are given by:

$$M1=Si1/So1 \quad (1)$$

$$M2=Si2/So2 \quad (2).$$

Hence, the ratio of upper side vs. lower side of the image projected on the screen SC is given by:

$$R=M2/M1=(Si1\cdot So2)/(So1\cdot Si2) \quad (3).$$

By utilizing the ratio R, an image pattern to be formed in an image-forming region of the liquid crystal display panel **32***b* provided In the liquid crystal light valve **32** can be corrected. Specifically, by previously forming an image pattern, which has been subjected to the trapezoidal correction with a ratio resulting from reversal of the ratio R, in the liquid crystal display panel **32***b*, it becomes possible to project an image having no distortion in its rectangular profile onto the screen SC.

[0040] The distances Si**1**, Si**2**, So**1** and So**2** are given by:

$$Si1=b(1-\tan\beta\times\tan\theta2/(1+\tan\beta\times\tan\theta2))=b/(1+\tan\beta\times\tan\theta2),$$

$$Si2=b(1+\tan\beta\times\tan\theta1/(1-\tan\beta\times\tan\theta1))\ b/(1-\tan\beta\times\tan\theta1,$$

$$So1=a+(L/2)\sin\alpha, \text{ and}$$

$$So2=a-(L/2)\text{ s1n }\alpha,$$

where L is the lengthwise size of the liquid crystal light valve **32**.

[0041] Incidentally, since Si**1** is given by b−x and b×tan θ2=x/tan β+x tan θ2, Si**1** is given as described above utilizing x=b×tan θ**2**×tan β/1+tan β×tan θ**2**). Likewise, Si**2** is given by b+y, and therefore Si**2** is given as described above utilizing y=b×tan θ**1**×tan β/(1−tan β×tan θ**1**).

[0042] In addition, in the above expressions, tan β=(b/a) tan α. Further, in the case of α=0, when the liquid crystal light valve **32** is not tilted, θ1=θ2=θ˜=tan^{-1}(L/2a)'. Moreover, when it is assumed that spreading angles θ**1** and θ**2** of light at the upper and lower edges are reversed and maintained also on the side of the liquid crystal light valve **32**, the following expressions are given.

$$\tan\theta1=\tan\theta0\times\cos\alpha/(1-\tan\theta0\times\sin\alpha)$$

$$\tan\theta2=\tan\theta0\times\cos\alpha/(1+\tan\theta0\times\sin\alpha)$$

However, as for the angles θ**1** and θ**2**, the tilt angle α is small in general and as such, there is no problem even when an approximation such that θ**1**=θ**2**=θ˜ at all times is made.

[0043] The foregoing can be summarized as follows. The distances Si**1**, Si**2**, So**1** and So**2** can be determined when the tilt angle α obtained by the tilt sensor **92** and the distance b obtained by the distance sensor **93** are used as variables. Therefore, the ratio R of upper side vs. lower side of a projection image in the case of no correction is made can be determined. Thus, it becomes possible to readily determine the targeted amount of trapezoidal correction (upper side vs. lower side ratio)

[0044] Now, a method of using the projector **100** of the first embodiment will be described below. First, the projector **100** is placed on the stand **2** and arranged so that a whole projection image fits in the screen SC. Next, when a user operates the user-operating part **83**, a direction is sent to the image processing part **81** through the control part **85**. Then, a protected image composed of a focus-checking whole area pattern is formed in the whole liquid crystal light valve **32**, and a projected image of a focus mark is formed in the center position CT so as to be superposed on the whole area pattern image. In other words, the focus-checking whole area pattern is projected on an entire surface of the screen SC, and the focus mark is projected on the position CTS on the screen SC where the system optical axis SA goes through the screen. When using the focusing ring **46** to adjust the focus of the projection optical system **40**, the user uses the focus mark to check the focus. Subsequently, the user operates the user-operating part **83**, whereby a direction is sent to the driving circuit **84** through the control part **85** and then the tilt angle of the liquid crystal light valve **32** is increased or decreased appropriately. The user can use the focus-checking whole area pattern projected on the entire surface of the screen SC and operates the user-operating part **83** to adjust the tilt angle of the liquid crystal light valve **32** so that a projection image on the screen SC is focused not only on the position CTS, but also on the upper and lower edges of the screen. In the condition where a projection image is thus in focus on the entire surface of the screen SC, the requirement of Scheimpflug rule is satisfied. The control part **85** calculates the ratio R based on the expression (3), and forms an image pattern subjected to trapezoidal correction with a ratio resulting from reversal of the ratio R in the liquid crystal display panel **32***b*, whereby an image having no distortion is projected on the screen SC.

[**0045**] The operations as described above can be repeated two or more times, therefore, the position of the focusing ring **46** and the tilt angle of the liquid crystal light valve **32** can be readjusted by continuing superposing the focus mark on the image pattern after the trapezoidal correction. This enables more accurate focusing and trapezoidal correction.

[**0046**] After the focusing and trapezoidal correction are terminated, the user operates the user-operating part **83** thereby to send a direction to the image processing part **81** through the control part **85**, and then the focus-checking whole area pattern and the focus mark are erased from the projection image.

Second Embodiment

[**0047**] **FIG. 5** is a block diagram of assistance in partially conceptualizing a projector in association with the second embodiment. The projector of the second embodiment is a modification of the projector of the first embodiment, and therefore common parts are identified by the same reference character, and repeated description thereof are omitted. Further, in a portion which is not described particularly, the projector of the second embodiment shall have the same structure as that of the projector of the first embodiment.

[**0048**] The circuit device included in the projector of the second embodiment further includes an area focus sensor **195** and a lens-driving part **196**. The area focus sensor **195** is arranged so that it can detect an in focus condition in a center portion, an upper portion and a lower portion of an image projected on the screen SC. In addition, the lens-driving part **196** can force the focusing ring **46** to work by rote and automatically adjust the focus condition of the projection optical system **40**.

[**0049**] The operations of the projector of the second embodiment will be described below. First, the projector **100** is placed on the stand **2** and arranged so that a whole projection image fits the screen SC. Next, when a user operates the user-operating part **83**, a direction is sent to the control part **85**. Then, the focus adjustment and trapezoidal correction are performed automatically. Specifically, the direction is sent to the image processing part **81** through the control part **85**, a projected image having a focus-checking whole area pattern and a focus mark on and in the vicinity of the optical axis is formed (written) in the liquid crystal light valve **32**, and then the whole area pattern and the focus mark are projected on the screen SC. With the focus mark, the control part **85** uses the area focus sensor **195** and forces the lens-driving part **196** to work appropriately, thereby to adjust the focus of the projection optical system **40**. Subsequently, the control part **85** sends a direction to the driving circuit **84** thereby to appropriately increase and decrease the tilt angle of the liquid crystal light valve **32**. In other words, as for the whole area pattern, the control part **85** uses the area focus sensor **195** and adjusts the tilt angle of the liquid crystal light valve **32** so that a projection image on the screen SC is in focus on the upper and lower edges of the screen. Thus, a projection image is focused on the entire surface of the screen SC and therefore the requirement of Scheimpflug rule is satisfied automatically. Finally, the control part **85** calculates the ratio R based on the expression (**3**), and forms an image pattern subjected to trapezoidal correction with a ratio resulting from reversal of the ratio R in the liquid crystal display panel **32***b*, whereby an image with no distortion is projected on the screen SC.

[**0050**] While the invention has been described based on the embodiments above, it is not limited to the embodiments. For example, in the embodiments, the rotation-driving device **34** forces the liquid crystal light valve **32** to rotate around X-axis using the center position CT as a fulcrum. However, the liquid crystal light valve **32** may be made to rotate about Y-axis. In this case, the principle is the same as that used in the former case, and the description of the detail is omitted. However, the focusing in the right and left direction and trapezoidal correction as well as the focusing in the up and down direction and trapezoidal correction are made possible.

[**0051**] In addition, the above liquid crystal light valve **32** was of a single-panel type. However, the liquid crystal light valve **32** may include e.g. red, blue and green liquid crystal light valves separately. Also, with a projector of a type such that individual color images formed in such color valves are combined, it is possible to perform trapezoidal correction of a projection image on the screen based on tilt angles of the liquid crystal light valves and the distance from the projection optical system to the screen while adjusting the tilting amounts of the liquid crystal light valves to meet the requirement of Scheimpflug rule.

[**0052**] The liquid crystal light valve **32** may be replaced with a reflection type tilt mirror device. Also, in this case, trapezoidal correction of a projection image on the screen can be performed based on the tilt angle of the tilt mirror device and the distance from the projection optical system to the screen while generally adjusting the tilting amount of the tilt mirror device to meet the requirement of Scheimpflug rule.

[**0053**] The entire disclosure of Japanese Patent Application No. 2005-176026, filed Jun. 16, 2005 is expressly incorporated by reference herein.

What is claimed is:

1. A projector comprising:

a light-modulation device for modulating an illumination light according to a piece of image information;

a projection optical system for projecting a modulated light resulting from the modulation by the light-modulation device as an image on a screen;

a movable holder capable of holding the light-modulation device in a condition where the light-modulation device is tilted with respect to an optical axis; and

a control-processing device which corrects a trapezoidal distortion of an image projected on the screen by correcting an image formed in the light-modulation device based on a distance from the projection optical system to the screen and a tilt angle of the light-modulation device, when the light-modulation device is arranged in satisfying a requirement of Scheimpflug rule to the projection optical system and the screen.

2. The projector of claim 1, wherein the projection optical system has a focusing ring for focus adjustment, and

the control-processing device determines the distance to the screen based on an output from a distance sensor for detecting a piece of distance information concerning the focusing ring.

3. The projector of claim 2, further comprising a tilt sensor for detecting a piece of information on the tilt angle of the light-modulation device,

wherein the control-processing device gains a piece of information on a tilt condition of the screen with respect to the optical axis based on outputs from the tilt sensor and the distance sensor.

4. The projector of claim 1, wherein the movable holder forces the light-modulation device to rotate around a center position thereof where the optical axis goes through the light-modulation device, and

the control-processing device writes a piece of information for checking a focusing condition in the center position of the light-modulation device or in a nearby position thereof when adjusting a tilting amount of the light-modulation device.

5. A projection method, by which a light-modulation device modulates an illumination light according to a piece of image information thereby to attain a modulated light, and the modulated light is projected, as an image, on a screen by a projection optical system, comprising the steps of:

arranging the light-modulation device in satisfying a requirement of Scheimpflug rule to the projection optical system and the screen, by holding the light-modulation device so as to form a predetermined tilt angle with respect to an optical axis; and

correcting a trapezoidal distortion of an image projected on the screen, by correcting an image formed in the light-modulation device based on a distance from the projection optical system to the screen and the tilt angle of the light-modulation device.

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