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PROJECTION SYSTEM AND VIEWING ASSIST DEVICE

Abstract

A projection system includes an illuminating device and an optical filter. The illuminating device emits illuminating light. The illuminating device projects a projected pattern onto a surface of projection. An average transmittance of the optical filter in a wavelength region of the illuminating light emitted from the illuminating device is higher than an average transmittance of the optical filter in a visible light wavelength region other than the wavelength region of the illuminating light.

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Background/Summary

TECHNICAL FIELD

[0001] The present invention relates to a projection system and a viewing assist device.

BACKGROUND ART

[0002] There has been known an illuminating device configured to project a projected pattern onto a surface of projection such as a road surface (e.g. JP2021-52008A). Depending on ambient light in an environment in which the illuminating device is used, the projected pattern become so low in contrast that it becomes hard to view the projected pattern.

DISCLOSURE OF INVENTION

[0003] The present disclosure has as an object to make it possible to clearly view a projected pattern.

[0004] In an embodiment of the present disclosure, there is provided a projection system including an illuminating device configured to emit illuminating light and project a projected pattern onto a surface of projection and an optical filter configured such that an average transmittance of the optical filter in a wavelength region of the illuminating light is higher than an average transmittance of the optical filter in a visible light wavelength region other than the wavelength region of the illuminating light. The wavelength region of the illuminating light is a wavelength region ranging from a wavelength that is 5 nm lower than a peak wavelength of the illuminating light to a wavelength that is 5 nm higher than the peak wavelength. The peak wavelength of the illuminating light is a wavelength at which a maximum radiant flux of the illuminating light is attained.

[0005] In an embodiment of the present disclosure, there is provided a first viewing assist device configured to assist viewing of a projected pattern that is projected onto a surface of projection with use of illuminating light emitted from an illuminating device. The first viewing assist device includes an optical filter configured such that an average transmittance of the optical filter in a wavelength region of the illuminating light is higher than an average transmittance of the optical filter in a visible light wavelength region other than the wavelength region of the illuminating light. The wavelength region of the illuminating light is a wavelength region ranging from a wavelength that is 5 nm lower than a peak wavelength of the illuminating light to a wavelength that is 5 nm higher than the peak wavelength. The peak wavelength of the illuminating light is a wavelength at which a maximum radiant flux of the illuminating light is attained.

[0006] In an embodiment of the present disclosure, there is provided a second viewing assist device configured to assist viewing of a pattern displayed on a surface. The second viewing assist device includes a display device configured to display an image taken of the surface and a control device electrically connected to the display device. The control device detects the pattern in the image displayed on the display device and generates a display pattern associated with the pattern thus detected. The display device displays the display pattern over the image.

[0007] An embodiment of the present disclosure makes it possible to clearly view a projected pattern.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0008] FIG. **1** is a diagram explaining an embodiment and a perspective view showing an example of a projection system and an example of a viewing assist device.

[0009] FIG. **2**A is a perspective view showing an example of a viewing assist device.
[0010] FIG. **2**B is a perspective view showing a viewer wearing the viewing assist device shown in FIG. **2**A.
[0011] FIG. **2**C is a perspective view showing a modification of the viewing assist device shown in FIG. **2**A.
[0012] FIG. **3**A is a perspective view showing another example of a viewing assist device.
[0013] FIG. **3**B is a perspective view showing a viewer wearing the viewing assist device shown in FIG. **3**A.
[0014] FIG. **4** is a side view showing still another example of a viewing assist device, together with a viewer.
[0015] FIG. **5** is a sectional side view showing still another example of a viewing assist device.
[0016] FIG. **6** is a side view showing another example of a projection system and another example of a viewing assist device.
[0017] FIG. **7**A is a graph showing an example of a transmission spectrum of an optical filter that can be included in a projection system and a viewing assist device.
[0018] FIG. **7**B is a cross-sectional view showing an example of a layer configuration of an optical filter that can be included in a projection system and a viewing assist device.
[0019] FIG. **8** is a perspective view showing an example of an illuminating device.
[0020] FIG. **9** is a perspective view showing another example of an illuminating device.
[0021] FIG. **10** is a cross-sectional view showing still another example of an illuminating device.
[0022] FIG. **11** is a side view showing still another example of an illuminating device.
[0023] FIG. **12** is a diagram explaining still another example of an illuminating device.
[0024] FIG. **13** is a side view showing still another example of a viewing assist device.
[0025] FIG. **14** is a plan view showing a display device that can be included in the viewing assist device of FIG. **13**.
[0026] FIG. **15** is a longitudinal sectional view showing an example of a movable body.
[0027] FIG. **16** is a perspective view showing an wearable display device.
[0028] FIG. **17** is a side view showing still another example of a projection system and still another example of a viewing assist device.
[0029] FIG. **18**A is a diagram corresponding to FIG. **14** and showing a display surface of the display device.
[0030] FIG. **18**B is a diagram corresponding to FIG. **14** and showing the display surface of the display device.
[0031] FIG. **18**C is a diagram corresponding to FIG. **14** and showing the display surface of the display device.
[0032] FIG. **18**D is a diagram corresponding to FIG. **14** and showing the display surface of the display device.
[0033] FIG. **18**E is a diagram corresponding to FIG. **14** and showing the display surface of the display device.
[0034] FIG. **19** is a flow chart showing an example of a method for generating a display pattern with a control device.
[0035] FIG. **20** is a side view showing still another example of a projection system and still another example of a viewing assist device.
[0036] FIG. **21** is a side view showing still another example of a projection system and still another example of a viewing assist device.
[0037] FIG. **22** is a plan view showing a modification of a projected pattern and a modification of a display pattern.
[0038] FIG. **23** is a plan view showing another modification of a projected pattern and another modification of a display pattern.
[0039] FIG. **24** is a diagram corresponding to FIG. **14** and showing the display surface of the

display device.
[0040] FIG. **25** is a diagram corresponding to FIG. **1** and a perspective view explaining a conventional problem.

DESCRIPTION OF EMBODIMENTS

[0041] An embodiment of the present disclosure relates to [1] to [40] below.

[1]

[0042] A projection system including: [0043] an illuminating device configured to emit illuminating light and project a projected pattern onto a surface of projection; and [0044] an optical filter configured such that an average transmittance of the optical filter in a wavelength region of the illuminating light is higher than an average transmittance of the optical filter in a visible light wavelength region other than the wavelength region of the illuminating light, [0045] wherein [0046] the wavelength region of the illuminating light is a wavelength region ranging from a wavelength that is 5 nm lower than a peak wavelength of the illuminating light to a wavelength that is 5 nm higher than the peak wavelength, and [0047] the peak wavelength of the illuminating light is a wavelength at which a maximum radiant flux of the illuminating light is attained.

[2]

[0048] The projection system according to [1], wherein the projected pattern is viewed via the optical filter.

[3]

[0049] The projection system according to [1] or [2], further including a wearable tool that a viewer of the projected pattern is able to wear, [0050] wherein [0051] the wearable tool includes the optical filter, and [0052] in a state where the viewer is wearing the wearable tool, the optical filter faces eyes of the viewer.

[4]

[0053] The projection system according to [3], wherein [0054] the wearable tool includes a light-shielding wall portion located around the optical filter, and [0055] in a state where the viewer is wearing the wearable tool, the light-shielding wall portion is located between the optical filter and the viewer.

[5]

[0056] The projection system according to [3] or [4], wherein [0057] the wearable tool includes a wearable tool body that is worn on a head, and [0058] the optical filter is detachable from the wearable tool body.

[6]

[0059] The projection system according to [3], wherein the wearable tool includes a contact lens including the optical filter.

[7]

[0060] The projection system according to [1] or [2], wherein the optical filter constitutes a windshield of a movable body.

[8]

[0061] The projection system according to [1], further including an imaging device including the optical filter.

[9]

[0062] The projection system according to [8], further including a display device electrically connected to the imaging device, [0063] wherein the display device displays an image taken by the imaging device.

[10]

[0064] The projection system according to [9], wherein [0065] the display device includes a wearable tool that a viewer is able to wear and a display element held by the wearable tool and configured to display the image, and [0066] in a state where the viewer is wearing the wearable tool, the display element faces eyes of the viewer.

[11]
[0067] The projection system according to [10], wherein a total transmittance of the display element is 1% or higher.
[12]
[0068] The projection system according to any one of [9] to [11], further including a control device electrically connected to the imaging device and the display device, [0069] wherein [0070] the control device detects the projected pattern in the image displayed on the display device and generates a display pattern associated with the projected pattern thus detected, and [0071] the display device displays the display pattern over the image.
[13]
[0072] The projection system according to [12], wherein [0073] the projected pattern includes a linear pattern, and [0074] the display pattern includes a linear auxiliary pattern extending as an extension of the projected pattern.
[14]
[0075] The projection system according to [12] or [13], wherein [0076] the projected pattern includes a straight linear pattern, and [0077] the display pattern includes a straight linear auxiliary pattern located on an extension of the projected pattern.
[15]
[0078] The projection system according to [12] or [13], wherein [0079] the projected pattern includes a first linear pattern and a second linear pattern that intersect each other, and [0080] the display pattern includes a linear first auxiliary pattern located on an extension of the first linear pattern and a linear second auxiliary pattern located on an extension of the second linear pattern.
[16]
[0081] The projection system according to [12] or [13], wherein the display pattern includes an auxiliary pattern circumferentially surrounding the projected pattern.
[17]
[0082] The projection system according to [16], wherein a center of gravity of a region surrounded by an outer contour of the auxiliary pattern is in a position that is identical to that of at least either a center of gravity of the projected pattern or a center of gravity of a region surrounded by an outer contour of the projected pattern.
[18]
[0083] The projection system according to any one of [12] to [17], wherein the display pattern includes a detection pattern overlapping the projected pattern thus detected.
[19]
[0084] The projection system according to any one of [12] to [18], wherein the display pattern includes an auxiliary pattern connected to the detection pattern and located on an extension of the detection pattern.
[20]
[0085] The projection system according to any one of [9] to [19], wherein [0086] the imaging device is able to move relative to the surface of projection, and [0087] the display device displays, over the image, a reference pattern indicating a predetermined position, a predetermined direction, or a predetermined range within a range that is imaged by the imaging device.
[21]
[0088] The projection system according to [20], further including a movable body that is able to move relative to the surface of projection, [0089] wherein the imaging device is held by the movable body.
[22]
[0090] The projection system according to [21], wherein the reference pattern indicates at least either a scheduled route of movement of the movable body or a scheduled position of work that is carried out by the movable body.

[23]
[0091] The projection system according to any one of [12] to [22], wherein [0092] the display device displays, over the image, a reference pattern indicating a predetermined position, a predetermined direction, or a predetermined range within a range that is imaged by the imaging device, [0093] the control device evaluates a positional relationship between the reference pattern and at least either the projected pattern thus detected or the display pattern thus generated, and [0094] in a case where the control device determines that there is an abnormality in the positional relationship, the abnormality is notified.
[24]
[0095] The projection system according to [23], wherein the display device notifies the abnormality by changing at least either a method for displaying the image or a method for displaying the display pattern.
[25]
[0096] The projection system according to [23] or [24], further including a notification device configured to notify the abnormality, [0097] wherein in a case where the control device determines that there is an abnormality in the positional relationship, the notification device notifies the abnormality using at least either light or sound.
[26]
[0098] The projection system according to any one of [23] to [25], wherein the illuminating device notifies the abnormality by changing a method for projecting the projected pattern onto the surface of projection.
[27]
[0099] The projection system according to any one of [1] to [26], wherein the optical filter includes a dielectric multilayer film.
[28]
[0100] The projection system according to any one of [1] to [27], wherein a full width at half maximum of a spectral transmittance of the optical filter is 15 nm or less.
[29]
[0101] The projection system according to any one of [1] to [28], wherein a maximum spectral transmittance of the optical filter in a visible light region is 50% or higher.
[30]
[0102] The projection system according to any one of [1] to [29], wherein an average transmittance of the optical filter in a visible light wavelength region other than a wavelength region of 30 nm centered at the peak wavelength of the illuminating light is 1% or lower.
[31]
[0103] The projection system according to any one of [1] to [30], wherein an average transmittance of the optical filter in a visible light wavelength region other than a wavelength region of 30 nm centered at the peak wavelength of the illuminating light is 0.001% or higher.
[32]
[0104] The projection system according to any one of [1] to [31], wherein a maximum value of an illuminance of the projected pattern projected onto the surface of projection is 1 lx or greater.
[33]
[0105] The projection system according to any one of [1] to [32], wherein an illuminance LX (lx) that is a maximum value of an illuminance of the projected pattern projected onto the surface of projection, an illuminance LY (lx) attributed to ambient light at a position on the surface of projection at which the illuminance LX is attained, an average transmittance TX (%) of the optical filter in the wavelength region of the illuminating light, and an average transmittance TY (%) of the optical filter in a visible light wavelength region other than a wavelength region of 30 nm centered at the peak wavelength of the illuminating light satisfy 0.001≤(LX.Math.TX)/(LY.Math.TY).
[34]

[0106] The projection system according to [33], wherein the illuminance LX, the illuminance LY, the transmittance TX, and the transmittance TY satisfy (LX.Math.TX)/(LY.Math.TY)≤10.
[35]
[0107] The projection system according to any one of [1] to [34], wherein the illuminating device includes a light source configured to emit coherent light as the illuminating light and a diffraction optical element configured to diffract the coherent light.
[36]
[0108] A viewing assist device configured to assist viewing of a projected pattern that is projected onto a surface of projection with use of illuminating light emitted from an illuminating device, the viewing assist device including an optical filter configured such that an average transmittance of the optical filter in a wavelength region of the illuminating light is higher than an average transmittance of the optical filter in a visible light wavelength region other than the wavelength region of the illuminating light, [0109] wherein [0110] the wavelength region of the illuminating light is a wavelength region ranging from a wavelength that is 5 nm lower than a peak wavelength of the illuminating light to a wavelength that is 5 nm higher than the peak wavelength, and [0111] the peak wavelength of the illuminating light is a wavelength at which a maximum radiant flux of the illuminating light is attained.
[37]
[0112] The viewing assist device according to [36], further including a wearable tool that a viewer of the projected pattern is able to wear, [0113] wherein [0114] the wearable tool includes the optical filter, and [0115] in a state where the viewer is wearing the wearable tool, the optical filter faces eyes of the viewer.
[38]
[0116] The viewing assist device according to [36] or [37], further including an imaging device including the optical filter.
[39]
[0117] A viewing assist device configured to assist viewing of a pattern displayed on a surface, the viewing assist device including: [0118] a display device configured to display an image taken of the surface; and [0119] a control device electrically connected to the display device, [0120] wherein [0121] the control device detects the pattern in the image displayed on the display device and generates a display pattern associated with the pattern thus detected, and [0122] the display device displays the display pattern over the image.
[40]
[0123] The viewing assist device according to [39], further including an illuminating device configured to project the pattern onto a surface.
[0124] In the following, an embodiment of the present disclosure is described with reference to the drawings. In the accompanying drawings, scales and horizontal and vertical dimensional ratios, or other sizes are alterations and exaggerations of actual ones for convenience of illustration and ease of comprehension.
[0125] A plurality of upper-limit candidates and a plurality of lower-limit candidate are lined up herein for a range of numerical values. In this description, the range of numerical values may be constituted by a combination of any one of the upper-limit candidates and any one of the lower-limit candidates. Let some thought be given to the following statement: “A parameter B is for example A1 or greater, may be A2 or greater, or may be A3 or greater. The parameter B may be A4 or less, may be A5 or less, or may be A6 or less.” In this example, the range of numerical values of the parameter B may be A1 or greater and A4 or less, may be A1 or greater and A5 or less, may be A1 or greater and A6 or less, may be A2 or greater and A4 or less, may be A2 or greater and A5 or less, may be A2 or greater and A6 or less, may be A3 or greater and A4 or less, may be A3 or greater and A5 or less, or may be A3 or greater and A6 or less.
[0126] For clarification of directional relationships among drawings, some drawings show a first

direction D**1**, a second direction D**2**, and a third direction D**3** by arrows as directions that are common among the drawings. A first side of each of the directions D**1**, D**2**, and D**3** is indicated by the head of an arrow. An arrow pointing toward the back of a paper surface of a drawing along a direction perpendicular to the paper surface is indicated by a symbol with an “x” provided in a circle, for example, as shown in FIG. **6**. An arrow pointing toward the front of a paper surface of a drawing along a direction perpendicular to the paper surface is indicated by a symbol with a dot provided in a circle, for example, as shown in FIG. **10**.

[0127] Terms such as “parallel”, “orthogonal”, and “identical”, values of length and angle, or other terms and values that are used herein to specify shapes, geometric conditions, and their extent are not bound by strict meanings but construed as encompassing the extent to which similar functions may be expected.

[0128] A projection system **10** according to the present embodiment includes an illuminating device **30** and a viewing assist device **100**. The illuminating device **30** projects a projected pattern **90** onto a surface of projection **95**. A viewer **5** can view the projected pattern **90** on the surface of projection **95**. In the present embodiment, which will be described below, devices are made to make it possible for the viewer **5** to clearly view the projected pattern **90**. Specifically, the projection system **10** includes the viewing assist device **100**. The viewing assist device **100** includes an optical filter **120**. An average transmittance of the optical filter **120** in a wavelength region of illuminating light emitted from the illuminating device **30** is higher than an average transmittance of the optical filter **120** in a visible light wavelength region other than the wavelength region of the illuminating light. Using the optical filter **120** allows the viewer **5** to clearly view the projected pattern **90**.

[0129] In the following, an embodiment is described with reference to specific examples shown in the drawings.

[0130] The illuminating device **30** projects the illuminating light onto an illuminated region **96** of the surface of projection **95**. The viewer **5** recognizes the illuminated region **96** as the projected pattern **90**. The projected pattern **90** has a shape that is identical to that of the illuminated region **96**.

[0131] The surface of projection **95** is not limited to particular surfaces of projection that are illuminated with the illuminating light from the illuminating device **30**. In particular, according to the present embodiment, the viewing assist device **100** brings about improvement in viewability of the projected pattern **90**. Accordingly, the surface of projection **95** may be a surface that is illuminated with sunlight as shown in FIG. **1**. Examples of the surface of projection **95** onto which the projected pattern **90** is projected include: a road surface; a ground surface of a sidewalk, a playground, a park, or other places; a water surface such as a sea surface; and an outer wall surface, an inner wall surface, a passage, a floor, a ceiling, or other parts of a building structure such as a school, a company, a building, a factory, an assembly hall, a lecture hall, a gymnasium, a stadium, or a meeting place.

[0132] The projected pattern **90** and the illuminated region **96** are not limited to particular patterns and regions. The projected pattern **90** and the illuminated region **96** may include a single region. The projected pattern **90** and the illuminated region **96** may include a plurality of regions that are away from each other. The projected pattern **90** may include any one or more of a letter, a picture, a geometric pattern, a symbol, a mark, an illustration, a character, and a pictogram. The projected pattern **90** may display information.

[0133] In the example shown in FIG. **1**, the projected pattern **90** and the illuminated region **96** have a linear shape. The projected pattern **90** and the illuminated region **96** are in the shape of a line that extends away from an installation position of the illuminating device **30**. The projected pattern **90** and the illuminated region **96** are in the shape of a straight line. The projected pattern **90** and the illuminated region **96** have long sides in the first direction D**1**. The projected pattern **90** and the illuminated region **96** have short sides in the second direction D**2**.

[0134] The illuminating light that the illuminating device **30** projects onto the surface of projection

95 is in a particular wavelength region. The illuminating light may be coherent light. The coherent light is light having a constant wavelength and a constant phase. The illuminating light may include coherent light of a single wavelength. The illuminating light may be green light of a wavelength of 520 nm. The illuminating light may be green light of a wavelength of 530 nm. The illuminating light may be red light of a wavelength of 635 nm. The illuminating light may be red light of a wavelength of 638 nm. The illuminating light may include coherent light of a plurality of wavelengths. The illuminating light may be visible light.

[0135] The viewing assist device **100** includes the optical filter **120**. A transmittance of the optical filter **120** has wavelength dependence. The optical filter **120** selectively transmits illuminating light of the visible light that is emitted from the illuminating device **30**. The visible light is light having a wavelength that is 380 nm or longer and 780 nm or shorter. More specifically, the average transmittance of the optical filter **120** in the wavelength region of the illuminating light that is emitted from the illuminating device **30** is higher than the average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of the illuminating light.

[0136] An average transmittance (%) is defined as an arithmetic mean value of spectral transmittances per 1 nm in a target wavelength region. A spectral transmittance (%) is a transmittance for a wavelength k (nm) in the target wavelength region, and k is a natural number. The wavelength region of the illuminating light is a wavelength region that is defined as ranging from a wavelength that is 5 nm lower than a peak wavelength of the illuminating light to a wavelength that is 5 nm higher than the peak wavelength.

[0137] For example, when the peak wavelength is 500 nm, the wavelength region of the illuminating light is a wavelength region ranging from 495 nm to 505 nm. In this example, the "average transmittance in the wavelength region of the illuminating light" is an arithmetic mean value of spectral transmittances (%) for wavelengths of 495 nm, 496 nm, 497 nm, 498 nm, 499 nm, 500 nm, 501 nm, 502 nm, 503 nm, 504 nm, and 505 nm. In this example, the "average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of the illuminating light" is an arithmetic mean value of spectral transmittances (%) measured every 1 nm in a wavelength region ranging from 380 nm to 494 nm and a wavelength region ranging from 506 nm to 780 nm.

[0138] The spectral transmittances are measured in compliance with JIS Z 8722:2009. Measurement of the spectral transmittances involves the adoption of a geometric condition e defined in JIS Z8722:2009. The spectral transmittances are measured in a measurement environment with a temperature of **23**° C. +2° C. and a relative humidity of 50% ±5%. A sample is placed for sixteen hours in the measurement environment before the start of the measurement. A light source is a D65 light source. The light source is kept turned on for fifteen minutes before the start of the measurement so that the light source stabilizes its output.

[0139] The peak wavelength of the illuminating light is a wavelength (nm) in a visible light region at which a maximum radiant flux (W) of the illuminating light is attained. The peak wavelength of the illuminating light is defined as a natural number (nm). The peak wavelength is measured with a light spectrum analyzer. The peak wavelength is measured in compliance with a method for measuring a peak oscillation wavelength described in JIS C 5941:1997. Note, however, that the illuminating light to be measured is deemed as light emitted from a rated semiconductor laser. The peak wavelength is measured in a measurement environment with a temperature of 23° C.±2° C., a relative humidity of 50% ±5%, and an atmospheric pressure that is 860 hPa or higher and 1060 hPa or lower. The illuminating device is kept turned on for fifteen minutes before the start of the measurement so that the illuminating device stabilizes its output.

[0140] As shown in FIGS. **2**A to **5**, the projection system **10** and the viewing assist device **100** may include a wearable tool **104** that the viewer **5** is able to wear. The wearable tool **104** includes the optical filter **120**. In a state where the viewer **5** is wearing the wearable tool **104**, the optical filter

120 faces the eyes of the viewer **5**. By viewing the projected pattern **90** via the optical filter **120**, the viewer **5** can clearly view the projected pattern **90**, for example, even in a bright environment.

[0141] As shown in FIG. **2**A, the wearable tool **104** may be glasses. The wearable tool **104** may be sunglasses. FIG. **2**B shows the viewer **5** wearing the sunglasses of FIG. **2**A. As shown in FIGS. **2**A and **2**B, the wearable tool **104** may include optical filters **120**, a frame **106**, and light-shielding wall portions **105**. In the specific example shown in FIGS. **2**A and **2**B, the frame **106** holds the optical filters **120**. The frame **106** includes a frame body **106**A configured to hold the optical filters **120** and holding portions **106**B configured to allow the viewer **5** to hold the frame body **106**A. As is the case with normal glasses, the frame body **106**A holds one optical filter **120** facing the right eye and holds one optical filter **120** facing the left eye. The holding portions **106**B are temples. The light-shielding wall portions **105** are located around the optical filters **120**. As shown in FIG. **2**B, in a state where the viewer **5** is wearing the wearable tool **104**, the light-shielding wall portions **105** are located between the optical filters **120** and the viewer **5**. The light-shielding wall portions **105** have a visible light-shielding effect. The light-shielding wall portion **105** may have a function of absorbing visible light. The light-shielding wall portions **105** may have a function of reflecting visible light. Providing the light-shielding wall portions **105** makes it possible to restrain ambient light from laterally entering a space between the eyes of the viewer **5** and the optical filters **120**.

[0142] FIG. **2**C shows another specific example of a wearable tool. As shown in FIG. **2**C, the wearable tool **104** may be goggles. The goggles may include a pair of optical filters **120**. As shown in FIG. **2**C, the goggles may include a single optical filter **120**. In the example shown in FIG. **2**C, in a state where the viewer **5** is wearing the wearable tool **104**, the eyes of the viewer **5** face the single optical filter **120**. The wearable tool **104** shown in FIG. **2**C includes an optical filter **120** and a frame **106**. The frame **106** includes a frame body **106**A configured to hold the optical filter **120** and a holding portion **106**B configured to fix the frame body **106**A to the viewer **5**. The holding portion **106**B may be a piece of rubber that is held on the head of the viewer **5**. The holding portion **106**B has a pair of ends connected separately to each end of the frame body **106**A. The frame body **106**A also serves as a light-shielding wall portion **105**. The frame body **106**A serving as the light-shielding wall portion **105** is connected to all sides of the optical filter **120**. In a state where the viewer is wearing the wearable tool **104**, the frame body **106**A serving as the light-shielding wall portion **105** is located between the optical filter **120** and the viewer **5**. The frame body **106**A serving as the light-shielding wall portion **105** can restrain ambient light from laterally entering a space between the optical filter **120** and the viewer **5**.

[0143] As shown in FIGS. **3**A and **3**B, the wearable tool **104** may be goggles. In the example shown in FIGS. **3**A and **3**B, an optical filter **120** curved along the face of the viewer **5** is in direct contact with the face of the viewer **5**. Holding portions **106**B are connected to both ends of the optical filter **120**. The pair of holding portions **106**B may be pieces of rubber or strings. As shown in FIG. **3**B, each holding portion **106**B may be hung over an ear on a corresponding side. In the example shown in FIG. **3**B, in a state where the wearable tool **104** is worn, a peripheral edge of the optical filter **120** is in contact with the face of the viewer **5**. This makes it possible to restrain ambient light from laterally entering a space between the optical filter **120** and the viewer **5**.

[0144] As shown in FIG. **4**, the wearable tool **104** includes an optical filter **120** and a wearable tool body **107** that is worn on the head. The wearable tool body **107** may be a helmet. The wearable tool body **107** may be a cap. The optical filter **120** may be goggles. The optical filter **120** is attached to the wearable tool body **107**. When the viewer **5** puts the wearable tool body **107** on the head, the optical filter **120** faces in front of the eyes of the viewer **5**. In the illustrated example, as in the case of the example of FIG. **3**B, a peripheral edge of the optical filter **120** is in contact with the face of the viewer **5**. This makes it possible to restrain ambient light from laterally entering a space between the optical filter **120** and the viewer **5**. The optical filter **120** may be detachable from the wearable tool body **107**.

[0145] As shown in FIG. **5**, the wearable tool **104** may be a contact lens. As the contact lens, the wearable tool **104** may include a contact lens body **108** and an optical filter **120** stacked on the contact lens body **108**. In a state where the viewer **5** is wearing the contact lens on an eye, the optical filter **120** faces the eye via the contact lens body **108**. At this point in time, the contact of the contact lens body **108** with the eye makes it possible to restrain ambient light from laterally entering a space between the optical filter **120** and the viewer **5**.

[0146] As shown in FIG. **15**, the optical filter **120** may be included in a windshield **81** of a movable body **80**. The movable body **80** is an apparatus that is able to move. The movable body **80** may be an automobile, a train, a ship, an airplane, or a drone. A person may or may not be able to board the movable body **80**. The windshield **81** may be installed in an opening such as a window of the movable body **80**. The windshield **81** may function as a windbreak. The windshield **81** may be a partitioning member **82** such as a window member that partitions the inside of the movable body **80** from the outside.

[0147] The viewer **5** may be able to view the outside of the movable body **80** across the windshield **81**. In this example, the viewer **5** can clearly view the projected pattern **90**, for example, even in a bright environment. In a case where ambient light is restrained from entering the movable body **80** through another opening or other parts of the movable body **80**, the viewer **5** can more clearly view the projected pattern **90**. As shown in FIG. **15**, the viewer **5** may operate the movable body **80**.

[0148] As shown in FIG. **6**, the projection system **10** and the viewing assist device **100** may include an imaging device **101**. The imaging device **101** includes the optical filter **120** and an imaging element **101***a*. Light having passed through the optical filter **120** falls on the imaging element **101***a*. The imaging device **101** images the surface of projection **95** including the illuminated region **96**. The viewer **5** views the surface of projection **95** as imaged by the imaging device **101**. This allows the viewer **5** to clearly view the projected pattern **90**, for example, even in a bright environment

[0149] As shown in FIG. **6**, the projection system **10** and the viewing assist device **100** may include a display device **102** electrically connected to the imaging device **101**. The display device **102** displays an image taken by the imaging device **101**. The viewer **5** can clearly view the projected pattern **90** as displayed on the display device **102**. The display device **102** may be a display device such as a liquid crystal display, a plasma display, an organic EL display, or a projection display device. The display device **102** may include a touch panel sensor configured to function as an input unit.

[0150] In a case where work is carried out only by viewing through the display device **102** the surface of projection **95** thus imaged, the illuminating light does not need to be limited to the visible light region. For example, the imaging device **101** may be an infrared camera. The illuminating light may be infrared light. A center wavelength of the optical filter may be in an infrared region.

[0151] As shown in FIG. **16**, the display device **102** may include a wearable tool **102**B and a display element **102**A. The viewer **5** is able to wear the wearable tool **102**B. The wearable tool **102**B holds the display element **102**A. In a state where the viewer **5** is wearing the wearable tool **102**B, the display element **102**A faces the eyes of the viewer **5**. In a state where the viewer **5** is wearing the wearable tool **102**B, the viewer **5** can view an image that is displayed on the display element **102**A. Such a display device **102** is a wearable display device.

[0152] The display device **102** may be VR (virtual reality) glasses, AR (augmented reality) glasses, or a head-mounted display. The wearable display device **102** may enable the viewer **5** to see through the wearable tool **102**B. In this example, a total transmittance of the wearable tool **102**B may be 1% or higher, may be 10% or higher, may be 30% or higher, may be 50% or higher, may be 60% or higher, may be 70% or higher, or may be 80% or higher.

[0153] In a case where work is carried out only by viewing an image from an imaging device or a sensor built in the display device **102**, the illuminating light does not need to be limited to the visible light region. For example, in a case where the imaging device or the sensor built in the display device **102** is an infrared camera or an infrared sensor, the illuminating light may be

infrared light and a center wavelength of the optical filter may be in an infrared region.
[0154] The is no particular upper limit set to the total transmittance of the wearable tool **102**B. For example, the total transmittance of the wearable tool **102**B may be **100**% or lower or may be lower than 100%.
[0155] Measurement of the total transmittance (%) involves the use of a D65 light source. The wavelength region of light that is used for the measurement of the total transmittance (%) ranges from 380 nm to 780 nm. The light source is kept turned on for fifteen minutes before the start of the measurement of the total transmittance of the display element **102**A so that the light source stabilizes its output. An angle of incidence on a sample during the measurement of the total transmittance is 0 degree. The total transmittance is measured in a measurement environment with a temperature of 23° C.±2° C. and a relative humidity of 50% ±5%. The sample is placed for sixteen hours in the measurement environment before the start of the measurement. Other measurement conditions for measuring the total transmittance comply with JIS K7361-1:1997.
[0156] FIG. **7**A shows an example of a transmission spectrum of the optical filter **120** in the visible light region. The optical filter **120** may selectively transmit only the illuminating light that is emitted from the illuminating device **30**. In the present embodiment, the average transmittance of the optical filter **120** in a wavelength region of the illuminating light is higher than the average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of the illuminating light. This allows the viewer **5** to clearly view the projected pattern **90** on the surface of projection **95** via the optical filter **120** even if the amount of ambient light such as sunlight that is shone on the surface of projection **95** is large. In expectation of this function of the optical filter **120**, the wavelength region of the illuminating light that is emitted from the illuminating device **30** may be sufficiently narrowed. From this aspect, the illuminating light may be coherent light. The illuminating light may be laser light of a particular wavelength.
[0157] A lower limit may be set to the average transmittance of the optical filter **120** in the wavelength region of the illuminating light. Setting a lower limit to this average transmittance allows the illuminating light to pass through the optical filter **120** with a high transmittance. The viewer **5** can clearly view the projected pattern **90** via the optical filter **120**. The average transmittance of the optical filter **120** in the wavelength region of the illuminating light may be 50% or higher, may be 70% or higher, or may be 80% or higher.
[0158] No particular upper limit is set to the average transmittance of the optical filter **120** in the wavelength region of the illuminating light. The average transmittance of the optical filter **120** in the wavelength region of the illuminating light may be 100% or lower or may be lower than 100%. The average transmittance of the optical filter **120** in the wavelength region of the illuminating light may be 50% or higher and 100% or lower.
[0159] Similarly, a lower limit may be set to a maximum spectral transmittance of the optical filter **120** in the visible light region. Setting a lower limit to the maximum spectral transmittance allows the illuminating light to pass through the optical filter **120** with a high transmittance. The viewer **5** can clearly view the projected pattern **90** via the optical filter **120**. The maximum spectral transmittance of the optical filter **120** in the visible light region may be 50% or higher, may be 70% or higher, or may be 80% or higher. It should be noted that in a case where the illuminating light has a single wavelength, the average transmittance (%) of the optical filter **120** in the wavelength region of the illuminating light and the maximum spectral transmittance (%) of the optical filter **120** in the visible light region may be identical to each other.
[0160] No particular upper limit is set to the maximum spectral transmittance of the optical filter **120** in the visible light region. The maximum spectral transmittance of the optical filter **120** in the visible light region may be 100% or lower or may be lower than 100%. The maximum spectral transmittance of the optical filter **120** in the visible light region may be 50% or higher and 100% or lower.
[0161] A full width at half maximum FWHM of a spectral transmittance of the optical filter means

the width (nm) of a wavelength region in a wavelength distribution of spectral transmittances at which a transmittance half or more than half of a maximum transmittance is attained. An upper limit may be set to the full width at half maximum FWHM of the spectral transmittance of the optical filter. Setting an upper limit to the full width at half maximum FWHM enables the illuminating light in the particular wavelength region to pass intensively through the optical filter **120**. In a case where the wavelength region of the illuminating light is narrow, e.g. a case where the illuminating light is coherent light or a case where the illuminating light is laser light, the illuminating light can pass intensively through the optical filter **120**. At the same time, ambient light such as sunlight can be restrained from passing through the optical filter **120**. This makes it possible to, when viewing the projected pattern **90** via the optical filter **120**, emphasize the projected pattern **90** with the ambient light dimmed. This makes it possible to bring about improvement in contrast of the projected pattern **90**. This makes it possible to clearly view the projected pattern **90**. From this point of view, the full width at half maximum FWHM of the spectral transmittance of the optical filter may be 15 nm or less, may be 3 nm or less, or may be 1 nm or less.

[0162] No particular lower limit is set to the full width at half maximum FWHM of the spectral transmittance of the optical filter. The full width at half maximum FWHM of the spectral transmittance of the optical filter may be greater than 0 nm. The full width at half maximum FWHM of the spectral transmittance of the optical filter may be 0 nm or greater and 15 nm or less.

[0163] An upper limit may be set to the average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of the illuminating light. Setting an upper limit to this average transmittance makes it possible to restrain ambient light such as sunlight from passing through the optical filter **120**. This brings about improvement in contrast of the projected pattern **90**, making it possible to clearly view the projected pattern **90**. The average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of the illuminating light may be 1% or lower, may be 0.1% or lower, or may be 0.01% or lower.

[0164] A lower limit may be set to the average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of the illuminating light. Setting a lower limit to this average transmittance makes it possible to grasp a relative position of the projected pattern **90** with respect to an ambient environment via the optical filter **120** even in a case such as nighttime where the amount of ambient light is small. This makes it possible to, while making the handling of the optical filter **120** the same for both a case where the surface of projection **95** is bright and a case where the surface of projection **95** is dark, clearly view the projected pattern **90** via the optical filter **120** in both of the cases. The average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of the illuminating light may be 0.001% or higher, may be 0.005% or higher, or may be 0.01% or higher.

[0165] The average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of the illuminating light may be 0.001% or higher and 1% or lower.

[0166] An upper limit may be set to an average transmittance of the optical filter **120** in a visible light wavelength region other than a wavelength region of **30** nm centered at the peak wavelength of the illuminating light. Setting an upper limit to this average transmittance makes it possible to, in a case where the wavelength region of the illuminating light is narrow, e.g. a case where the illuminating light is coherent light or a case where the illuminating light is laser light, restrain ambient light such as sunlight from passing through the optical filter **120** and allow the illuminating light to pass intensively through the optical filter **120**. This enables the illuminating light in the particular wavelength region to pass intensively through the optical filter **120**. The average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of 30 nm centered at the peak wavelength of the illuminating light may be 1% or lower, may be 0.1% or lower, or may be 0.01% or lower.

[0167] A lower limit may be set to the average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of 30 nm centered at the peak wavelength of the illuminating light. Setting a lower limit to this average transmittance makes it possible to grasp the relative position of the projected pattern **90** with respect to the ambient environment via the optical filter **120** even in a case such as nighttime where the amount of ambient light is small. This makes it possible to, while making the handling of the optical filter **120** the same for both a case where the surface of projection **95** is bright and a case where the surface of projection **95** is dark, clearly view the projected pattern **90** via the optical filter **120** in both of the cases. The average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of 30 nm centered at the peak wavelength of the illuminating light may be 0.001% or higher, may be 0.005% or higher, or may be 0.01% or higher.
[0168] The average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of 30 nm centered at the peak wavelength of the illuminating light may be 0.001% or higher and 1% or lower.
[0169] As mentioned above, in a case where a plurality of upper-limit candidates and a plurality of lower-limit candidate are lined up herein for a range of numerical values such as transmittances, full widths at half maximum, and illuminances, the range of numerical values may be constituted by a combination of any one of the upper-limit candidates and any one of the lower-limit candidates.
[0170] The optical filter **120** is not limited to particular optical filters as long as it has wavelength-selective transparency. The optical filter **120** may include a dielectric multilayer film **122**. The dielectric multilayer film **122** is superior in being high in the degree of freedom of design of a transmission property.
[0171] FIG. **7**B is a cross-sectional view showing an example of a layer configuration of an optical filter **120**. The optical filter **120** shown in FIG. **7**B includes a first protective layer, a second protective layer, and a dielectric multilayer film **122** located between the first protective layer **121**A and the second protective layer **121**B.
[0172] The dielectric multilayer film **122** may include low-refractive-index layers **122***a* and high-refractive-index layers **122***b* that are alternately stacked. The low-refractive-index layers **122***a* and the high-refractive-index layers **122***b* may be inorganic layers containing an inorganic compound. The low-refractive-index layers **122***a* and the high-refractive-index layers **122***b* may be resin layers.
[0173] A dielectric multilayer film including inorganic layers is obtained by alternately stacking high-refractive-index organic layers and low-refractive-index organic layers, for example, by a CVD method, a sputtering method, a vacuum deposition method, a wet coating method, or other methods. The thickness of a multilayer film of an inorganic compound may be 0.5 μm or greater and 10 μm or less. The refractive index of an inorganic compound contained in a high-refractive index layer may be 1.7 or higher and 2.5 or lower. Examples of an inorganic compound contained in a high-refractive index layer are composed mainly of titanium oxide, zirconium oxide, tantalum pentoxide, niobium pentoxide, lanthanum oxide, yttrium oxide, zinc oxide, zinc sulfide, or indium oxide and contain a small amount of titanium oxide, tin oxide, cerium oxide, or other substances. The refractive index of an inorganic compound contained in a low-refractive index layer may be 1.2 or higher and 1.6 or lower. Examples of an inorganic compound contained in a low-refractive index layer include silica, alumina, lanthanum fluoride, magnesium fluoride, and aluminum sodium hexafluoride.
[0174] A dielectric multilayer film **122** including resin layers may include a large number of layers of thermoplastic resin and thermosetting resin. The resin layers may have added thereto various types of additives such as an antioxidant, an antistatic agent, a crystal nucleating agent, inorganic particles, organic particles, a thinner, a thermal stabilizer, a lubricant, an infrared ray absorbing agent, an ultraviolet ray absorbing agent, a dopant for refractive index adjustment. An in-plane

average refractive index difference between a high-refractive-index resin layer having a high refractive index and a low-refractive-index resin layer having a low refractive index may be 0.03 or greater, may be 0.05 or greater, or may be 0.1 or greater.

[0175] The number of high-refractive-index resin layers and low-refractive-index resin layers that are stacked is adjusted according to reflection and transmission properties required of the optical filter **120**. For example, thirty or more high-refractive-index resin layers and thirty or more low-refractive-index resin layers can be alternately stacked, or two hundred or more high-refractive-index resin layers and two hundred or more low-refractive-index resin layers may be stacked. Further, the total number of high-refractive-index resin layers and low-refractive-index resin layers may, for example, be 600 or larger.

[0176] Examples of a method for manufacturing a resin multilayer film that constitutes a dielectric multilayer film include a coextrusion method. Specifically, a method for manufacturing a laminated film described in JP2008200861A can be referred to.

[0177] The first protective layer **121**A and the second protective layer **121**B may contain polyethylene terephthalate or polyethylene naphthalate. The thicknesses of the first protective layer **121**A and the second protective layer **121**B may be 3 μm or greater or may be 5 μm or greater.

[0178] The dielectric multilayer film **122** transmits light of a particular wavelength region and reflects light of a wavelength region other than the particular wavelength region. Light having passed through the optical filter **120** and entered the space between the eyes of the viewer **5** and the optical filter **120** travels toward the eyes of the viewer. Meanwhile, ambient light having laterally entered the space between the eyes of the viewer **5** and the optical filter **120** can fall on a surface of the optical filter **120** that faces the viewer **5** and be reflected with a high reflectance. This reflection causes the surface of the optical filter **120** that faces the viewer **5** to act like a mirror to decrease the viewability of the projected pattern **90**. As mentioned above, the entrance of ambient light such as sunlight into the space between the eyes of the viewer **5** and the optical filter **120** may be restrained by the optical filter **120** making contact with the face of the viewer **5**. The lateral entrance of ambient light such as sunlight into the space between the eyes of the viewer **5** and the optical filter **120** may be restrained by using the light-shielding wall portion **105**. An average transmittance of the light-shielding wall portion **105** in the visible light wavelength region may be 0%.

[0179] The following describes workings in which the projection system **10** and the viewing assist device **100** are used.

[0180] As shown in FIG. **1**, the illuminating device **30** emits the illuminating light. The illuminating light is shone on the illuminated region **96** of the surface of projection **95**. The viewer **5** can view the projected pattern **90** on the surface of projection **95**. The projected pattern **90** has a shape that is identical to that of the illuminated region **96**. The projected pattern **90** may display various types of information.

[0181] For example, the projected pattern **90** may show the viewer **5**, who performs work, a region on which the work is to be carried out. The worker, who is the viewer **5**, can utilize the projected pattern **90** in drawing a white line or an orange line, for example, on a road, a sidewalk, or a parking lot. Without being limited to this example, the projected pattern **90** may display the direction of an arrow or other signs. According to this example, the projected pattern **90** may display a route of movement route or a route of evacuation. Further, the projected pattern **90** may be letters, numbers, or other words or signs. This example makes it possible to present necessary information directly to the viewer **5**. Furthermore, the projected pattern **90** may be an advertisement.

[0182] Incidentally, depending on ambient light in an environment in which an illuminating device **30**X is used, there is a decrease in contrast of a projected pattern **90**X. At this point in time, a viewer **5**X cannot clearly view the projected pattern **90**X on a surface of projection **95**X. As shown in FIG. **25**, in a case where the amount of ambient light such as sunlight is large, an illuminance (lx) on the surface of projection **95**X increases. The contrast of the projected pattern **90**X projected onto the surface of projection **95**X remarkably decreases. The viewer **5**X cannot accurately view the shape of the projected pattern **90**X. Furthermore, the viewer **5**X cannot even notice the presence of the projected pattern **90**X on the surface of projection **95**X.

[0183] In the present embodiment, a projection system **10** includes a viewing assist device **100** in addition to an illuminating device **30**. The viewing assist device **100** includes an optical filter **120**. An average transmittance of the optical filter **120** in a wavelength region of illuminating light that is emitted from the illuminating device **30** is higher than an average transmittance of the optical filter **120** in a visible light wavelength region other than the wavelength region of the illuminating light. Viewing a projected pattern **90** via the optical filter **120** makes it possible to reduce the brightness of ambient light while maintaining the brightness of the projected pattern **90**. This makes it possible to bring about improvement in contrast of the projected pattern **90** and clearly view the projected pattern **90**.

[0184] In each of the examples shown in FIGS. **2** to **5**, the viewing assist device **100** includes a wearable tool **104**. In a state where the viewer **5** is wearing the wearable tool **104**, the optical filter **120** faces the eyes of the viewer **5**. That is, by wearing the wearable tool **104**, the viewer **5** can view the projected pattern **90** and a surface of projection **95** via the optical filter **120**. Since the viewer **5** does not need to hold the optical filter **120** with his/her hands, the viewer **5** can freely use both hands while clearly viewing the projected pattern **90**. For example, the viewer **5** can stably carry out work or other tasks while clearly viewing the projected pattern **90**.

[0185] The wearable tool **104** shown in FIGS. **2**A to **2**C may be glasses, sunglasses, or goggles. The wearable tool **104** illustrated includes a light-shielding wall portion **105** located around the optical filter **120**. In a state where the viewer **5** is wearing the wearable tool **104**, the light-shielding wall portion **105** is located between the optical filter **120** and the viewer **5**. Shielding of the ambient light by the light- shielding wall portion **105** makes it possible to restrain the ambient light from laterally entering the space between the optical filter **120** and the viewer **5**. Accordingly, when the optical filter **120** used is of a reflective type, a decrease in viewability of the projected pattern **90** due to the reflection of the ambient light off the optical filter **120** can be restrained.

[0186] The wearable tool **104** shown in FIG. **5** is a contact lens. Also in this example, the viewer **5** does not need to hold the optical filter **120** with his/her hands. Accordingly, the viewer **5** can freely use both hands while viewing the projected pattern **90**. Further, a contact lens body **108** is located between the optical filter **120** and the eyes of the viewer **5**. This makes it possible to restrain incidence and reflection of the ambient light on a surface of the optical filter **120** that faces the eyes of the viewer **5**.

[0187] In the example shown in FIG. **15**, the optical filter **120** constitutes a windshield **81** of a movable body **80**. Also in this example, the viewer **5** does not need to hold the optical filter **120** with his/her hands. In the example shown in FIG. **15**, the viewer **5** is on board the movable body **80** and is operating the movable body **80**.

[0188] In the example shown in FIG. **6**, the viewing assist device **100** includes an imaging device **101**. The imaging device **101** images the projected pattern **90** via the optical filter **120**. The imaging device **101** significantly reduces the ambient light through the optical filter **120** and images the projected pattern **90** and an area therearound. Accordingly, using the imaging device **101** makes it possible to clearly view the projected pattern **90**. In the example shown in FIG. **6**, the viewing assist device **100** includes a display device **102** electrically connected to the imaging device **101**. The display device **102** displays an image taken by the imaging device **101**, i.e. the projected pattern **90**. The display device **102** displays the projected pattern **90** with improvement in contrast. The viewer **5** can clearly view the projected pattern **90** as displayed by the display device **102**.

[0189] As mentioned above, the average transmittance of the optical filter **120** in the wavelength region of the illuminating light that is emitted from the illuminating device **30** may be 50% or higher, may be 70% or higher, or may be 80% or higher. The maximum transmittance in the visible light region of the optical filter **120** may be 50% or higher, may be 70% or higher, or may be 80%

or higher. The wavelength region of the illuminating light that is emitted from the illuminating device **30** may include a wavelength at which the transmittance of the optical filter **120** reaches its maximum. These examples make it possible to maintain the brightness of the projected pattern **90** in viewing the projected pattern **90** via the optical filter **120**. This makes it possible to clearly view the projected pattern **90**.

[0190] The average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of the illuminating light that is emitted from the illuminating device **30** may be 1% or lower, may be 0.1% or lower, or may be 0.01% or lower. The average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of 30 nm centered at the peak wavelength of the illuminating light that is emitted from the illuminating device **30** may be 1% or lower, may be 0.1% or lower, or may be 0.01% or lower. These examples make it possible to restrain ambient light such as sunlight from passing through the optical filter **120**. This brings about improvement in contrast of the projected pattern **90**, making it possible to clearly view the projected pattern **90**.

[0191] The full width at half maximum FWHM of the spectral transmittance of the optical filter may be 15 nm or less, may be 3 nm or less, or may be 1 nm or less. This example makes it possible to reduce the ambient light while maintaining the brightness of the projected pattern **90** in viewing the projected pattern **90** via the optical filter **120**. This brings about improvement in contrast of the projected pattern **90**, making it possible to clearly view the projected pattern **90**. The full width at half maximum FWHM of the spectral transmittance of the optical filter may include the whole of the wavelength region of the illuminating light that is emitted from the illuminating device **30**.

[0192] The average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of the illuminating light that is emitted from the illuminating device **30** may be 0.001% or higher, may be 0.005% or higher, or may be **0.01**% or higher. The average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of 30 nm centered at the peak wavelength of the illuminating light that is emitted from the illuminating device **30** may be 0.001% or higher, may be 0.005% or higher, or may be 0.01% or higher. These examples make it possible to grasp a relative position of the projected pattern **90** with respect to an ambient environment via the optical filter **120** even in a case such as nighttime where the amount of ambient light is small. This makes it possible, for example, to, while making the handling of the optical filter **120** the same for both a case where the surface of projection **95** is bright and a case where the surface of projection **95** is dark, clearly view the projected pattern **90** via the optical filter **120** in both of the cases.

[0193] A lower limit may be set to a maximum value of an illuminance of the projected pattern **90** projected onto the surface of projection **95**. The “illuminance of the projected pattern **90** projected onto the surface of projection **95**” here means an illuminance on the surface of projection **95** attributed solely to the illuminating light emitted from the illuminating device **30**. Accordingly, a difference between an illuminance that is measured at a certain position on the surface of projection **95** with the projected pattern **90** projected and an illuminance that is measured at the same position on the surface of projection **95** with the projected pattern **90** not projected is the “illuminance of the projected pattern **90** projected onto the surface of projection **95**”. Setting a lower limit to the maximum value of the illuminance of the projected pattern **90** makes it possible to brightly and clearly view the projected pattern **90**. The maximum value of the illuminance of the projected pattern **90** projected onto the surface of projection **95** may be 1 lx or greater, may be 0.1 lx or greater, or may be 0.01 lx or greater.

[0194] An upper limit may be set to the maximum value of the illuminance of the projected pattern **90** projected onto the surface of projection **95**. Increasing the illuminance of the projected pattern **90** too much hinders effective improvement in viewability of the projected pattern **90**, causing deterioration in energy efficiency. From this point of view, the maximum value of the illuminance of the projected pattern **90** projected onto the surface of projection **95** may be 10000 lx or less, may be 1000 lx or less, may be 100 lx or less, or may be 10 lx or less.

[0195] Let it be assumed that the maximum value of the illuminance of the projected pattern **90** projected onto the surface of projection **95** is an illuminance LX (lx). Let it also be assumed that an illuminance attributed to ambient light at a position on the surface of projection **95** at which the illuminance LX is attained is an illuminance LY (lx). The illuminance LY is measured on the surface of projection **95** with the projected pattern **90** not projected. Let it be assumed that the average transmittance of the optical filter **120** in the wavelength region of the illuminating light that is emitted from the illuminating device **30** is a transmittance TX (%). Let it also be assumed that the average transmittance of the optical filter **120** in the visible light wavelength region other than the wavelength region of 30 nm centered at the peak wavelength of the illuminating light that is emitted from the illuminating device **30** is a transmittance TY (%). At this point in time, the illuminance LX, the illuminance LY, the transmittance TX, and the transmittance TY may satisfy 0.001≤(LX.Math.TX)/(LY.Math.TY). This example brings about improvement in contrast of the projected pattern **90**, making it possible to clearly view the projected pattern **90**. From the point of view of improving the viewability of the projected pattern **90**, "(LX.Math.TX)/(LY.Math.TY)" may be 0.01 or greater or may be 0.1 or greater.

[0196] The illuminance LX, the illuminance LY, the transmittance TX, and the transmittance TY may satisfy (LX.Math.TX)/(LY.Math.TY)≤10.

[0197] This example makes it possible to restrain the area around the projected pattern **90** from becoming too dark. This makes it possible to grasp a relative position of the projected pattern **90** with respect to an ambient environment via the optical filter **120** even in a case where the amount of ambient light is small. This makes it possible, for example, to, while making the handling of the optical filter **120** the same for both a case where the surface of projection **95** is bright and a case where the surface of projection **95** is dark, clearly view the projected pattern **90** via the optical filter **120** in both of the cases.

[0198] Let it be assumed that an illuminance is a value measured using a Konica Minolta's spectroradiometer CL-500A in compliance with JIS(JIS C 1609-1:2006). Let it be assumed that wavelengths of measurement range from 380 nm to 780 nm. Intervals between wavelengths of measurement are 1 nm. Measurements are made with an illuminometer placed on the surface of projection **95**.

[0199] The following describes a specific configuration of the illuminating device **30**.

[0200] As shown in FIG. **8**, the illuminating device **30** may include a light source **40**, a shaping optical system **45**, and a diffraction optical element **50**. The light source **40** emits illuminating light. The light source **40** is not limited to particular light sources. The light source **40** may emit coherent light having a constant wavelength and a constant phase. The coherent light that is emitted from the light source **40** is superior in straightness. Accordingly, the light source **40** is suitable to an illuminating device **30** configured to illuminate a distant place. Usable examples of the light source **40** include various types of light source. As the light source **40**, a laser light source configured to emit laser light may be used. A possible example of the laser light source is a semiconductor laser light source. In the example shown in FIG. **8**, the light source **40** includes a single coherent light source. Accordingly, in the example shown in FIG. **8**, the illuminated region **96** is illuminated with color coherent light that corresponds to a wavelength region of the coherent light that is emitted from the light source **40**. The following describes an example in which the light source **40** emits coherent light.

[0201] The shaping optical system **45** shapes light emitted from the light source **40**. For example, the shaping optical system **45** shapes a cross-sectional shape of the illuminating light orthogonal to an optical axis and a steric shape of the illuminating light or the coherent light. The shaping optical system **45** may enlarge the cross-sectional area of the coherent light in a cross-section orthogonal to the optical axis of the coherent light.

[0202] In the example shown in FIG. **8**, the shaping optical system **45** shapes the light emitted from the light source **40** into a widened parallel pencil. That is, the shaping optical system **45** functions as a collimating optical system. In the example shown in FIG. **8**, the shaping optical system **45** has a first lens **46** and a second lens **47** that are arranged along an optical path. The first lens **46** shapes the light emitted from the light source **40** into a divergent pencil of rays. The second lens **47** shapes the divergent pencil of rays generated by the first lend **46** into a parallel pencil. In this example, the second lens **47** functions as a collimating lens.

[0203] The diffraction optical element **50** changes the direction of travel of the coherent light from the light source **40**. The coherent light diffracted by the diffraction optical element **50** is shone on the illuminated region **96** on the surface of projection **95**. The diffraction optical element **50** diffracts the coherent light from the light source **40** and directs it toward the illuminated region **96** on the surface of projection **95**. As a result of this, the surface of projection **95** is illuminated with the light diffracted by the diffraction optical element **50**. A projected pattern **90** corresponding to a diffraction pattern in the diffraction optical element **50** is projected onto the surface of projection **95**.

[0204] The diffraction optical element **50** may be a hologram element. Using a hologram element as the diffraction optical element **50** makes it easy to design the diffraction characteristics of the diffraction optical element **50**. This makes it possible to comparatively easily design a hologram element that can shine light only on the whole of a desired region on the surface of projection **95** that has a predetermined position, a predetermined contour shape, a predetermined size, and a predetermined orientation. A region on the surface of projection **95** that is illuminated with the coherent light serves as the illuminated region **96**.

[0205] In designing the diffraction optical element **50**, the illuminated region **96** is set in an actual space in a predetermined contour shape, size, and orientation in a predetermined position with respect to the diffraction optical element **50**. The position, contour shape, size, and orientation of the illuminated region **96** on the surface of projection **95** depend on the diffraction characteristics of the diffraction optical element **50**. The position, contour shape, size, and orientation of the illuminated region **96** on the surface of projection **95** can be arbitrarily adjusted by adjusting the diffraction characteristics of the diffraction optical element **50**. Accordingly, in designing the diffraction optical element **50**, the position, contour shape, size, and orientation of the illuminated region **96** on the surface of projection **95** are determined first. Then, the diffraction characteristics of the diffraction optical element **50** need only be adjusted so that the whole of the illuminated region **96** thus determined can be illuminated with light.

[0206] The diffraction optical element **50** can be fabricated as a computer-generated hologram (CGH). The computer-generated hologram is fabricated by calculating on a computer a structure having given diffraction characteristics. Accordingly, employing the computer-generated hologram as the diffraction optical element **50** can make it unnecessary to generate object light and reference light with use of a light source and an optical system or record interference fringes onto a hologram recording material by performing exposures. The illuminating device **30** is supposed to shine the illuminating light on the illuminated region **96** with a predetermined contour shape, size, and orientation in a predetermined position with respect to the illuminating device **30**. By inputting information regarding the illuminated region **96** as parameters into the computer, a structure having such diffraction characteristics as to be able to project diffracted light onto the illuminated region **96**, e.g. a corrugated surface, can be identified by computations on the computer. By forming the structure thus identified, for example, by resin shaping, the diffraction optical element **50** can be fabricated as a computer-generated hologram at low cost through a simple procedure.

[0207] The diffraction optical element **50** may be designed, for example, by using an iterative Fourier transform method. In a case where the iterative Fourier transform method is used, a process may be performed on the premise that the illuminated region **96** is far away from the diffraction optical element **50**, and the projected pattern **90** that is projected onto the surface of projection **95** may be a Fraunhofer diffraction image. Accordingly, the surface of projection **95** may be nonparallel with a diffractive surface of the diffraction optical element **50**.

[0208] As shown in FIG. **9**, the diffraction optical element **50** may include a plurality of elemental diffraction optical elements **55**. Each elemental diffraction optical element **55** is, for example, a hologram element and can be configured in the same manner as the aforementioned diffraction optical element **50**. In the example shown in FIG. **9**, coherent light diffracted by the plurality of elemental diffraction optical elements **55** is shone on the same illuminated region **96**. That is, light diffracted by each of the elemental diffraction optical elements **55** is shone on the whole of the illuminated region **96** on the surface of projection **95**. Such a diffraction optical element **50** allows light traveling toward various positions in the illuminated region **96** to be dispersedly emitted from the plurality of elemental diffraction optical elements **55** of the diffraction optical element **50**. This restrains each position on the diffraction optical element **50** from being too bright, making it possible to bring about improvement in lase safety.

[0209] The elemental diffraction optical elements **55** may be configured to be identical in diffraction characteristic to one another. Note, however, that in achieving higher-accuracy illumination, each of the elemental diffraction optical elements **55** may be given diffraction characteristics designed separately for that elemental diffraction optical element **55** according to the location of that elemental diffraction optical element **55** in the diffraction optical element **50**. According to this example, each of the elemental diffraction optical elements **55** has its diffraction characteristics adjusted according to a difference in location from the other elemental diffraction optical elements **55**, whereby diffracted light can be highly accurately directed solely to the whole of the illuminated region **96** on the surface of projection **95**.

[0210] Incidentally, an illuminating device **30** having a light source **40** configured to emit coherent light and a diffraction optical element **50** configured to diffract the coherent light can illuminate a large-area illuminated region **96** on a surface of projection **95** or an illuminated region **96** extending to a position distant from the illuminating device **30**. That is, a long and thin projected pattern **90** can be projected onto the surface of projection **95**. At this point in time, there are great variations in the angle of incidence a of the coherent light on various positions in the illuminated region **96**. The angle of incidence a on an illuminated region **96** far removed from the illuminating device **30** is very great, e.g. close to 90 degrees. The diffractive surface of the diffraction optical element **50** forms a great angle with respect to the surface of projection **95** and the illuminated region **96**. The angle of incidence a on the illuminated region **96** here is an angle that the direction of travel of the illuminating light forms with respect to a direction ND normal to the illuminated region **96**. In the illustrated example, the normal direction ND is parallel to the third direction D**3** orthogonal to both the first direction D**1** and the second direction D**2**.

[0211] In this illuminating device **30**, the diffraction optical element **50** adjusts an optical path of the coherent light. The diffraction optical element **50** has a high-accuracy optical path adjustment function. Accordingly, the optical path of the coherent light can be adjusted by the diffraction optical element **50** toward an illuminated region **96** of a desired shape. This makes it possible to, without being strongly bound by a position relative to the illuminating device **30**, set the illuminated region **96**, for example, also in a position far removed from the illuminating device **30**, a position where the angle of incidence a of the coherent light is greater, or other positions. That is, this makes it possible to significantly improve the degree of freedom in setting of the projected pattern **90** and the surface of projection **95**. As a result, the coherent light can be highly accurately shone on the illuminated region **96**. The projected pattern **90** can be precisely projected onto the surface of projection **95**.

[0212] According to a diffraction optical element **50** composed of a computer-generated hologram as an example, the direction of travel of coherent light coming from a certain direction can be adjusted with an accuracy of ±0.01 degree in an angular space. Using such a diffraction optical element **50** makes it possible to highly accurately illuminate an illuminated region **96** located at a distance of 1 m to 120 m from the diffraction optical element **50** or such an illuminated region **96** that the angle of incidence α of the coherent light on the illuminated region **96** is at least 30 degrees or greater and at most 89.99 degrees or less. Accordingly, the illuminating device **30** can highly accurately shine the coherent light on an illuminated region **96** located on the surface of projection **95**. This makes it possible to make the edges of a projected pattern **90** clear and allows an operator to view a remotely-located projected pattern **90**.

[0213] FIG. **10** shows a specific example configuration of an illuminating device **30**. The illuminating device **30** shown in FIG. **10** has portability. That is, the illuminating device **30** shown in FIG. **10** is able to be carried by an operator without using special means. The illuminating device **30** has a casing **70**. In the illuminating device **30** shown in FIG. **10**, the light source **40**, the shaping optical system **45**, and the diffraction optical element **50** are fixed to the casing **70**. During normal use, the light source **40**, the shaping optical system **45**, and the diffraction optical element **50** are not intended to be removed from the casing **70**. The light source **40**, the shaping optical system **45**, and the diffraction optical element **50** irremovable from the casing **70**. This causes the relative positions of the light source **40**, the shaping optical system **45**, and the diffraction optical element **50** to be maintained. This makes it possible to highly accurately and stably project a projected pattern **90** onto a surface of projection **95** that is in a predetermined relative positional relationship with the illuminating device **30**. This also restrains the light source **40**, the shaping optical system **45**, and the diffraction optical element **50** from being shifted from the predetermined positions, making it possible to bring about improvement in lase safety.

[0214] In the example shown in FIG. **10**, the shaping optical system **45** includes a first lens **46**, a second lens **47**, and a third lens **48**. The casing **70** includes a cylindrical portion **71** holding the light source **40** and the shaping optical system **45** and a lid portion **72** fixed to the cylindrical portion **71**. The cylindrical portion **71** has the shape of a cylinder having one end closed. The light source **40** is fixed to the closed end of the cylindrical portion **71**. The cylindrical portion **71** has an inner dimension that changes via stepped portions **71***a*. The inner diameter increases from an upstream side to a downstream side along an optical path of coherent light emitted from the light source **40**. The first lend **46** and the second lens **47** are attached separately to each of these two stepped portions **71***a*. Spacing rings **73** configured to highly accurately control a lens-to-lens distance are provided in the cylindrical portion **71**. A spacing ring **73** is placed between the first lens **46** and the second lens **47**. A spacing ring **73** is placed between the second lens **47** and the third lens **48**. Further, a spacing ring **73** is placed between the lid portion **72** and the third lens **48**. The spacing rings **73** restrain a shift in the relative position of each lens due to vibration or shock that is applied to the illuminating device **30**. Examples of the spacing rings **73** may be annular or cylindrical members. The spacing rings **73** may be made of metal such as aluminum or may be made of resin. An inorganic material such as fiberglass may be mixed into the resin to reduce the coefficient of thermal expansion. The spacing rings **73** make it possible to restrain a shift in the degree of parallelization of collimated light due to vibration or shock that is applied to the illuminating device **30**. That is, the spacing rings **73** can restrain the projected pattern **90** from becoming blurred on the surface of projection **95**. This makes it possible to keep the viewability of the projected pattern **90** high.

[0215] In order to keep the relative positions of the light source **40**, the shaping optical system **45**, the diffraction optical element **50**, or other constituent elements constant, the light source **40**, the shaping optical system **45**, and the diffraction optical element **50** may be fixed to the casing **70** by fixing involving the use of an adhesive or by the combined use of insertion fixing and adhesive fixing.

[0216] In order to adjust the relative positions of the light source **40**, the shaping optical system **45**, the diffraction optical element **50**, or other constituent elements in fine increments, for example, spacers may be used. Usable examples of the spacers may be thin plate-shaped members made of metal. The spacers may be used in combination with the spacing rings **73** and an adhesive.

[0217] Further, constituent elements such as the light source **40**, the shaping optical system **45**, and the diffraction optical element **50** may be held by a position adjusting holder configured to adjust the placement in fine increments. The position adjusting holder may make it possible to adjust the positions of the constituent elements in fine increments by operating an adjuster such as a screw. The constituent elements may be fixed to the casing **70** via the position adjusting holder. In a case where the position adjusting holder is used, the adjuster such as a screw may be fixed by an adhesive or other substances after the positions of the constituent elements have been adjusted. Further, the position adjusting holder may be used in combination with the aforementioned spacing rings **73** or other members configured to maintain the relative positions of constituent elements subjected to fine adjustments.

[0218] The casing **70** may be not able to be disassembled so that the relative positions of constituent elements such as the light source **40**, the shaping optical system **45**, and the diffraction optical element **50** may be maintained. For example, the relative positions of constituent elements positioned by a manufacturer of the illuminating device **30** may be maintained. For example, the casing **70** may be not able to be disassembled by applying an adhesive to a screwed portion or an inserted portion of the casing **70**.

[0219] In the example shown in FIG. **10**, the illuminating device **30** has a battery **74**, a circuit **75**, and a switch **76**. The battery **74** may be a primary battery or may be a secondary battery that can be charged and discharged. The circuit **75** is electrically connected to the battery **74** and the switch **76**. When the switch **76** is operated, the circuit **75** changes between feeding electricity from the battery **74** to the light source **40** and stopping feeding electricity from the battery **74** to the light source **40**.

[0220] The illuminating device **30** may be configured to be supplied with electric power from an external power source. For example, the casing may be provided with a connector to be electrically connected to the external power source. In this example, the illuminating device **30** may include a primary battery or a secondary battery or may not include a primary battery or a secondary battery. When the illuminating device **30** does not include a primary battery or a secondary battery, the illuminating device **30** is light in weight and therefore superior in resistance against vibration or shock.

[0221] The illuminating device **30** and the casing **70** may be waterproof. In order to make the illuminating device **30** waterproof, a waterproof member such as rubber or packing may be provided in a joint portion or an inserted portion of the casing **70**.

[0222] The illuminating device **30** may have a thermoregulation mechanism. The thermoregulation mechanism may keep the light source **40** and the circuit **75** at temperatures falling within a predetermined range. The thermoregulation mechanism may heat or cool the light source **40** and the circuit **75**. The thermoregulation mechanism may be installed in the casing **70**. Examples of the thermoregulation mechanism include a fan, a heater, and a cooler. As the thermoregulation mechanism, a heating wire, a Peltier element, or other components may be used.

[0223] As shown in FIG. **11**, an illuminating device **30** may include a scanning device **60**. The illuminating device **30** shown in FIG. **11** includes a plurality of diffraction optical elements **50**A to **50**C. By adjusting an optical path of coherent light emitted from the light source **40**, the scanning device **60** controls the presence or absence of the supply of the coherent light to the diffraction optical elements **50** and the distribution of the coherent light to the plurality of diffraction optical elements **50**A to **50**C. The scanning device **60** can be constituted using various components or other parts that can change the optical path by utilizing refraction, reflection, diffraction, or other phenomena. Examples of the various components that can change the optical path include lenses, prisms, mirrors, and diffraction optical elements.

[0224] The scanning device **60** temporally changes the optical path of the coherent light from the light source **40**. As a result of this, the positions of incidence of the coherent light on the plurality of diffraction optical elements **50**A to **50**C move. That is, the plurality of diffraction optical elements **50**A to **50**C replace one another as a diffraction optical element **50** on which the coherent light from the light source **40** falls. The scanning device **60** thus illustrated has a reflection surface that can rotate on one axis line RA. As such a scanning device **60**, a galvanometer mirror may be used.

[0225] The illuminated region **96** may be divided into a plurality of partial regions **93**A, **93**B, and **93**C according to locations in the first direction D**1**. The plurality of diffraction optical elements **50**A to **50**C may illuminate the different partial regions **93**A, **93**B, and **93**C. This example makes it possible to narrow a diffraction angle range of light that is diffracted by one diffraction optical element **50**. This brings about improvement in diffraction efficiency in each diffraction optical element **50**. Since the scanning device **60** operates at a speed that exceeds the resolution of human vision, all of the partial regions **93**A, **93**B, and **93**C included in the illuminated region **96** are viewed by a human as if they continue to be illuminated at the same time.

[0226] In the example shown in FIG. **12**, a diffraction optical element **50** includes first to twelfth diffraction optical elements **50**A to **50**L. For example, an illuminated region **96** on a surface of projection **95** is divided into first to twelfth partial regions **93**A to **93**L. Coherent light diffracted by the first to twelfth diffraction optical elements **50**A to **50**L is shone separately on each of the first to twelfth partial regions **93**A to **93**L. The scanning device **60** directs light from the light source **40** toward each of the diffraction optical elements **50**A to **50**L. The illuminating device **30** can control the presence or absence of the illumination of each of the diffraction optical elements **50**A to **50**L with light according to how the scanning device **60** operates. For example, the light source **40** changes, according to how the scanning device **60** operates, changes between emitting light and stopping emitting light. As another example, a light-shielding member configured to shield light enters or recedes from an optical path of the light from the light source **40** according to how the scanning device **60** operates. By controlling the presence or absence of the illumination of each of the diffraction optical elements **50**A to **50**L with light, the coherent light can be projected only onto any of the diffraction optical elements **50**A to **50**L. This makes it possible to illuminate only any of the first to twelfth partial regions **93**A to **93**L, making it possible to illuminate an area in a desired shape in the illuminated region **96**.

[0227] It should be noted that each of the diffraction optical elements **50** included in the illuminating device **30** shown in FIGS. **11** and **12** may be divided into a plurality of elemental diffraction optical elements **55**.

[0228] In the embodiment thus described, a projection system **10** includes an illuminating device **30** and an optical filter **120**. The illuminating device **30** emits illuminating light. The illuminating device **30** projects a projected pattern **90** onto a surface of projection **95**. An average transmittance of the optical filter **120** in a wavelength region of the illuminating light emitted from the illuminating device **30** is higher than an average transmittance of the optical filter **120** in a visible light wavelength region other than the wavelength region of the illuminating light. According to the present embodiment, viewing the projected pattern **90** via the optical filter **120** brings about improvement in contrast of the projected pattern **90** on the surface of projection **95**. This makes it possible to clearly view the projected pattern **90**.

[0229] In the embodiment thus described, a viewing assist device **100** assists viewing of a projected pattern **90** that is projected onto a surface of projection **95** with use of illuminating light emitted from an illuminating device **30**. The viewing assist device **100** includes an optical filter **120**. An average transmittance of the optical filter **120** in a wavelength region of the illuminating light emitted from the illuminating device **30** is higher than an average transmittance of the optical filter **120** in a visible light wavelength region other than the wavelength region of the illuminating light. The wavelength region of the illuminating light is a wavelength region ranging from a wavelength that is 5 nm lower than a peak wavelength of the illuminating light to a wavelength that is 5 nm higher than the peak wavelength. The peak wavelength of the illuminating light is a wavelength at which a maximum radiant flux of the illuminating light is attained. According to the present embodiment, viewing the projected pattern **90** via the optical filter **120** brings about improvement in contrast of the projected pattern **90** on the surface of projection **95**. Accordingly,

the viewing of the projected pattern **90** is assisted by the viewing assist device **100**, so that the projected pattern **90** can be clearly viewed.
[0230] While the embodiment has been described with reference to specific examples, the aforementioned specific examples are not intended to limit the embodiment. The aforementioned embodiment can be carried out in other various specific examples, and various omissions, substitutions, changes, additions, or other alterations can be made without departing from the scope of the embodiment.
[0231] The following describes modifications with reference to the drawings. In the following description and the drawings that are referred to in the following description, components that may be configured in a manner similar to those of the aforementioned specific examples are given reference signs that are identical to those given to the corresponding components of the aforementioned specific examples, and a repeated description of such components is omitted.
[0232] The aforementioned specific example has illustrated an example in which the viewing assist device **100** includes the imaging device **101** and the display device **102**. As shown in FIG. **13**, the imaging device **101** of the viewing assist device **100** may be mounted on the movable body **80**. In a case where the projected pattern **90** that is projected onto the surface of projection **95** by the illuminating device **30** indicates a route of movement of the movable body **80**, the viewer **5** can operate the movable body **80** while viewing an image that is displayed on the display device **102**.
[0233] FIG. **14** is a plan view showing a display surface **103** of the display device **102**. The imaging device **101** images a surface of projection **95** that is a road surface. A linear projected pattern **90** is projected onto the surface of projection **95**. The viewer **5** can operate the movable body **80** while viewing an image displayed on the display surface **103**. This allows the movable body **80** to move along a predetermined route of movement indicated by the projected pattern **90**.
[0234] As shown in FIG. **14**, the display device **102** may display a reference pattern **97** together with an image taken by the imaging device **101**. The reference pattern **97** may indicate a predetermined position, a predetermined direction, or a predetermined range within a range that is imaged by the imaging device **101**. The predetermined position, the predetermined direction, or the predetermined range may be a position, a direction, or a range on the surface of projection **95**.
[0235] In the example shown in FIG. **14**, the reference pattern **97** indicates a scheduled route of movement **99**A of the movable body **80** in a case where the movable body **80** keeps traveling in a way it currently is. That is, the reference pattern **97** indicates a scheduled position of passage of the movable body **80** within the range imaged by the imaging device **101**. The reference pattern **97** indicates a direction of movement of the movable body **80** within the range imaged by the imaging device **101**.
[0236] According to the example shown in FIG. **14**, causing the reference pattern **97**, which indicates the scheduled route of movement **99**A, and the projected pattern **90** to overlap each other on the display surface **103** of the display device **102** allows the movable body **80** to highly accurately move along the scheduled route of movement. Further, viewing an overlap between the reference pattern **97**, which indicates the scheduled route of movement **99**A, and the projected pattern **90** on the display surface **103** of the display device **102** makes it possible to confirm that the movable body **80** is moving along the scheduled route of movement.
[0237] It should be noted that the imaging device **101** may be attached to the movable body **80**. In this example, the imaging device **101** can display an image of a region that is in a certain relative relationship with the movable body **80**. In a case where the movable body **80** makes a certain movement such as traveling in a straight line, the movable body **80** passes through a certain position within the range displayed on the display device **102** of the imaging device **101**. The reference pattern **97**, which indicates the scheduled route of movement **99**A of such a movable body **80**, may be an image that is inputted as image data to the display device **102** and that is displayed on the display device **102** or may be a mark put on the display surface **103** with a writing instrument or a tape.

[0238] The movable body **80** may be a work vehicle configured to carry out some sort of work. The movable body **80** may carry out some sort of work while moving. In the example shown in FIG. **17**, the movable body **80** includes a work device **84**. The work device **84** can carry out predetermined work on the surface of projection **95**, on which the movable body **80** travels. As mentioned above, the work device **84** may be used for line-drawing work. The line-drawing work can involve drawing a white line or an orange line on a surface of a road, a sidewalk, a parking lot, or other places on which the work is to be carried out.
[0239] In an example in which the movable body **80** is a work vehicle, the projected pattern **90** may indicate a position on the surface of projection **95** at which the work should be carried out, a direction on the surface of projection **95** in which the work should be carried out, and a region on the surface of projection **95** in which the work should be carried out. In the example shown in FIG. **14**, the projected pattern **90** may be a predetermined route along which the work should be carried out.
[0240] In the example shown in FIG. **14**, the reference pattern **97** may indicate a scheduled route of work **99**B along which the movable body **80** carries out work in a case where the movable body **80** as a work vehicle keeps traveling in a way it currently is. That is, the reference pattern **97** may indicate a scheduled position of work by the movable body **80** within the range imaged by the imaging device **101**. The reference pattern **97** may indicate a direction in which the movable body **80** proceeds with the work within the range imaged by the imaging device **101**.
[0241] According to the example shown in FIG. **14**, causing the reference pattern **97**, which indicates the scheduled route of work **99**B, and the projected pattern **90** to overlap each other on the display surface **103** of the display device **102** allows the movable body **80** to highly accurately carry out the work along the planned route of work. Further, viewing an overlap between the reference pattern **97**, which indicates the scheduled route of work **99**B, and the projected pattern **90** on the display surface **103** of the display device **102** makes it possible to confirm that the movable body **80** is carrying out the work along the planned route of work.
[0242] Incidentally, under some environmental conditions such as weathers, it may be hard to view a projected pattern on a surface of projection. Further, it is necessary to increase output from an illuminating device to brightly display a large-area projected pattern. This causes an emission end of the illuminating device to glare. Furthermore, in the example shown in FIG. **18**A, the projected pattern **90** is in the shape of a line. The linear projected pattern **90** tends to be brightly displayed at a position on the surface of projection **95** that is close to the illuminating device **30**. The linear projected pattern **90** can be darkly displayed at a position on the surface of projection **95** that is far away from the illuminating device **30**. It can be hard to view the linear projected pattern **90** at a position on the surface of projection **95** that is far away from the illuminating device **30**.
[0243] To address such a problem, the projection system **10** and the viewing assist device **100** may have the following configuration.
[0244] As shown in FIG. **17**, the projection system **10** and the viewing assist device **100** may include a control device **130** electrically connected to the imaging device **101** and the display device **102**. The control device **130** detects the projected pattern **90** from the image displayed on the display device **102**.
[0245] The control device **130** generates a display pattern **92** associated with the projected pattern thus detected. The display device **102** displays the display pattern **92** over the image taken by the imaging device **101**.
[0246] FIG. **18**A shows the display surface **103** of the display device **102** of the projection system **10** and the viewing assist device **100** shown in FIG. **17**. In the example shown in FIG. **17**, the illuminating device **30** projects a projected pattern **90** as a linear pattern onto the surface of projection **95**. The linear pattern extends in a straight linear fashion in the first direction D**1** between the illuminating device **30** and the imaging device **101**.
[0247] In the examples shown in FIG. **18**A and FIGS. **18**B to **18**E, which will be referred to later,

the surface of projection **95** is a road. This road joins another road to form a T-shaped intersection. The projected pattern **90** extends in a straight linear fashion along the road from the T-shaped intersection. In the example shown in FIG. **18**A, the linear projected pattern **90** is viewed in an area near the T-shaped intersection that is away from the imaging device **101**.

[0248] In the example shown in FIG. **18**B, the display device **102** displays a display pattern **92** over the image taken by the imaging device **101**. The display pattern **92** includes a linear auxiliary pattern **93** extending as an extension of the projected pattern **80**. In the example shown in FIG. **18**B, the display pattern **92** is composed solely of the auxiliary pattern **93**. The auxiliary pattern **93** is a straight linear pattern as is the case with the projected pattern **90**.

[0249] In the example shown in FIG. **18**B, the display device **102** displays the projected pattern **90** that is viewed on the display surface **103** and the auxiliary pattern **93** connected to the projected pattern **90**. The projected pattern **90** and the auxiliary pattern **93** are displayed as a continuous line on the display surface **103** of the display device **102**.

[0250] The display by the display device **102** of the auxiliary pattern **93** generated by the control device **130** makes it possible to clearly view the whole of the projected pattern **90** even if some environment conditions or other conditions have made it hard to view a part of the projected pattern **90**. This makes it possible to stably carry out a scheduled movement or work in accordance with information indicated by the projected pattern **90**.

[0251] Further, on the premise that the auxiliary pattern **93** of the display pattern **92** is used, the projected pattern **90** may be a portion of a pattern originally intended to be displayed. The illuminated region **96** may be a portion of the pattern originally intended to be displayed. In this example, on the display surface **103**, the display pattern **92** is displayed in a region other than the illuminated region **96**. This example makes it possible to reduce output from the illuminating device **30** and restrain an emission end **31** of the illuminating device **30** from glaring.

[0252] The control device **130** may include a central processing unit (CPU) configured to operate in accordance with a predetermined program. The control device **130** may include an input unit such as a keyboard and a mouse. The control device **130** may include a storage unit such as a ROM and a RAM. The control device **130** may include a storage device such a semiconductor drive such as an SSD. The control device **130** may include a storage unit such as a cloud server.

[0253] The control device **130** may perform wireless or wired communication with the imaging device **101**. The control device **130** may acquire, from the imaging device **101**, image data taken by the imaging device **101**. The control device **130** may detect a projected pattern **90** using the image data acquired from the imaging device **101**.

[0254] The control device **130** may perform wireless or wired communicated with the display device **102**. The control device **130** may control a display content of the display device **102**. The display device **102** may be a display device such as a liquid crystal display, a plasma display, or an organic EL display. The display device **102** may include a touch panel sensor configured to function as an input unit.

[0255] FIG. **19** is a flow chart regarding a process by the control device **130**. The flow chart shown in FIG. **19** shows an example of a method for detecting a projected pattern **90** from an image acquired by the imaging device **101** and generating an auxiliary pattern **93** of a display pattern **92**. In this example, a linear projected pattern **90** is detected, and image data representing an auxiliary pattern **93** located on an extension of the projected pattern **90** is generated.

[0256] In the example shown in FIG. **19**, the auxiliary pattern **93** of the display pattern **92** is generated through steps S**1** to S**6**.

[0257] First, in a first step S**1**, a processing region R**130** is identified by trimming. For reductions of the amount of calculation and the duration of calculation, only image data that is displayed in some region of the display surface **103** is subjected to processing by the control device **130**. This region serves as the processing region R**130** (see FIG. **18**A). The processing region R**130** may be set in advance. The processing region R**130** may be set on an as-needed basis by a viewer **5** who views the display device **102**.

[0258] In a second step S**2**, only a particular wavelength component is extracted from the image data taken by the imaging device **101**. The particular wavelength to be extracted may be in a wavelength region of illuminating light emitted from the illuminating device **30**. The particular wavelength to be extracted may be in a wavelength region of **30** nm centered at a peak wavelength of the illuminating light. In a case where the image data taken by the imaging device **101** is a monochrome image, the second step S**2** is not needed.

[0259] In a third step S**3**, the image obtained in the second step is smoothed. A Gaussian filter or other devices are used to remove a high-frequency component from the image data.

[0260] In a fourth step S**4**, a group of dots that constitute the projected pattern **90** are searched for. Each dot may be one pixel of the display device **102**. In an example in which a straight linear projected pattern **90** is detected, a group of dots that constitute the projected pattern **90** may be searched for in the following manner.

[0261] First, a Y direction serving as a longitudinal direction and an X direction serving as a transverse direction are defined according to a pixel array of the display device **102**. Pixels with a maximum luminance are selected from among a plurality of pixels arrayed in the X direction that belong to the uppermost row in the Y direction. The pixels thus selected serve as candidates for the group of dots that constitute the projected pattern **90**. The luminance of a pixel is evaluated based on a gray level of the pixel.

[0262] Next, pixels with the maximum luminance are selected from among a plurality of pixels arrayed in the X direction that belong to a next row in the Y direction below the row from which the first candidates for the group of dots have been selected. An amount of shift in the X direction of the pixels thus selected and the pixels selected as the first candidates for the group of dots is compared with a column threshold set in advance. In a case where the amount of shift is less than or equal to the row threshold, the pixels thus selected are judged as candidates for the group of dots that constitute the projected pattern **90**. After that, pixels with the maximum luminance are searched for from among a plurality of pixels arranged in the X direction that belong to a next row in the Y direction below the row from which the latest candidates for the group of dots have been selected.

[0263] In a case where an amount of shift in the X direction of the pixels selected as pixels with the maximum luminance and the pixels most recently selected as candidates for the group of dots is greater than the column threshold, the pixels most recently selected are not included in the candidates for the group of dots. Next, the number of pixels selected as the candidates for the group of dots, i.e. the number of rows joined together one after another in the Y direction from which the candidates for the group of dots have been obtained, is compared with a row threshold set in advance. In a case where the number of rows is greater than the row threshold, the pixels selected as the candidates for the group of dots are judged as candidates for the group of dots that constitute the projected pattern **90**.

[0264] In a case where the number of rows is less than or equal to the row threshold, the pixels selected by then are eliminated from the candidates for the group of dots. Then, a search for new candidates for the group of dots from a next row in the Y direction below the row from which pixels with the maximum luminance have been most recently selected is started in the aforementioned manner.

[0265] In the foregoing way, the group of dots that constitute the projected pattern **90** is searched for. The foregoing process is carried out for each piece of image data that is taken by the imaging device **101**, e.g. for each piece of image data that is acquired at 10 frames per second. As for image data failing to meet conditions for the row threshold, it is judged that there is no group of dots that constitute a projected pattern **90**, i.e. that there is no projected pattern **90**.

[0266] In a fifth step S**5**, the projected pattern **90** is identified from the group of dots that constitute the projected pattern **90**. Identification of the straight linear projected pattern **90** may involve the use of the method of least squares. Identification of the straight linear projected pattern **90** may involve the use of image processing software "fitLine" of "OpenCV". The projected pattern **90** may be identified within a range of rows in the Y direction in which the group of dots that constitute the projected pattern **90** is included.

[0267] In a sixth step S**6**, an auxiliary pattern **93** is generated. In the fifth step, the position of the projected pattern **90** is identified as a function in an orthogonal coordinate system whose axes extend in the X direction and the Y direction. The auxiliary pattern **93** is identified as a function having a tilt that is identical to that of the projected pattern **90**. The auxiliary pattern **93** is identified as a function connected to one end of the projected pattern **90**. The auxiliary pattern **93** may extend to a column located at an end in the X direction or a row located at an end in the Y direction.

[0268] Thus, the position of the auxiliary pattern **93** on the image taken by the imaging device **101** is identified.

[0269] As shown in FIG. **18**C, the display pattern **92** may include a detection pattern **94**. The detection pattern **94** is displayed over the projected pattern **90**. That is, the detection pattern **94** is located on the projected pattern **90** thus detected. The detection pattern **94** is displayed on the illuminated region **96** in the display device **102**. Such an example makes it possible to brightly view the projected pattern **90** on the display surface **103** of the display device **102** regardless of environmental conditions. This makes it possible to stably carry out a scheduled movement or work in accordance with information indicated by the projected pattern **90**.

[0270] As shown in FIG. **18**C, the display pattern **92** may include both the auxiliary pattern **93** and the detection pattern **94**. In this example, the auxiliary pattern **93** may be connected to the detection pattern **94**. The auxiliary pattern **93** may be located on an extension of the detection pattern **94**. The display pattern **92** including the auxiliary pattern **93** and the detection pattern **94** makes it possible to brightly view the projected pattern **90** on the display surface **103** of the display device **102** regardless of environmental conditions. This makes it possible to stably carry out a scheduled movement or work in accordance with information indicated by the projected pattern **90**.

[0271] As shown in FIG. **18**C, the auxiliary pattern **93** and the detection pattern **94** may be displayed in different patterns. As shown in FIG. **18**D, the auxiliary pattern **93** and the detection pattern **94** may be displayed in identical patterns. As shown in FIG. **18**D, the display pattern **92** may include the auxiliary pattern **93** and the detection pattern **94** as one continuous pattern.

[0272] In each of the examples shown in FIGS. **18**A to **18**D, the display device **102** displays the reference pattern **97**. As mentioned above, the reference pattern **97** may indicate a predetermined position, a predetermined direction, or a predetermined range within a range that is imaged by the imaging device **101**. The reference pattern **97** may indicate the scheduled route of movement **99**A of the movable body **80**. The reference pattern **97** may indicate a scheduled position of work or a scheduled route of work **99**B by the work device **84** of the movable body **80**.

[0273] The control device **130** may evaluate a positional relationship between the reference pattern **97** and the projected pattern **90** thus detected. The control device **130** may evaluate a positional relationship between the reference pattern **97** and the display pattern **92** thus generated. The control device **130** may evaluate a positional relationship between the reference pattern **97** and the auxiliary pattern **93** thus generated. The control device **130** may evaluate a positional relationship between the reference pattern **97** and the detection pattern **94** thus generated.

[0274] In the aforementioned example, the position gap between each of the patterns **90**, **92**, **93**, and **94** and the reference pattern **97** on the display surface **103** of the display device **102** means that an actual route of movement of the movable body **80**, an actual position of passage of the movable body **80**, an actual route of work by the movable body **80**, an actual position of work by the movable body **80**, or other actual routes or positions are shifted from scheduled routes and positions of movement and work.

[0275] For example, in a case where a difference in positional relationship between each of the patterns **90**, **92**, **93**, and **94** and the reference pattern **97** in the aforementioned orthogonal coordinate system whose axes extend in the X direction and the Y direction reaches a certain level or higher, the control device **130** may determine that there is an "abnormality".

[0276] More specifically, the presence or absence of an abnormality may be evaluated by whether a difference or ratio in tilt between two patterns that are compared with each other falls within a predetermined range. The presence or absence of an abnormality may be evaluated by whether a difference in X coordinate between the Y coordinates of two patterns that are compared with each other falls within a predetermined range. The presence or absence of an abnormality may be evaluated by whether a difference in Y coordinate between the X coordinates of two patterns that are compared with each other falls within a predetermined range. The presence or absence of an abnormality may be evaluated by whether a sum of a difference in X coordinate between the Y coordinates of two patterns that are compared with each other and a difference in Y coordinate between the X coordinates of the two patterns falls within a predetermined range. The presence or absence of an abnormality may be evaluated by the distance between two patterns that are compared with each other.

[0277] In a case where the control device **130** determines that there is an abnormality in the positional relationship between the pattern **90**, **92**, **93**, or **94** thus detected or generated and the reference pattern **97**, the control device **130** may notify the abnormality. Notifying the abnormality facilitates a correction in position and orientation of the movable body **80**. For example, as shown in FIG. **18**E, the position and orientation of the movable body **80** is corrected so that the pattern **90**, **92**, **93**, or **94** thus detected or generated and the reference pattern **97** overlap each other. This enables the movable body **80** to move or carry out work in accordance with information displayed by the projected pattern **90**.

[0278] The control device **130** may notify the viewer **5** of an abnormality, for example, by a display or a sound that is outputted from the display device **102**. For example, at the time of an abnormality, a method for displaying an image taken by the imaging device **101** may be changed. At the time of an abnormality, a method for displaying the display pattern **92** on the imaging device **101** may be changed. At the time of an abnormality, a method for displaying the reference pattern **97** on the imaging device **101** may be changed. The control device **130** may display a warning on the display device **102**.

[0279] As shown in FIG. **17**, the projection system **10** and the viewing assist device **100** may include a notification device **86** configured to notify an abnormality. The notification device **86** may be a lamp or a beeper. In a case where the control device **130** determines that there is an abnormality in the positional relationship, the notification device **86** may notify the abnormality using at least either light or a sound.

[0280] The control device **130** may notify an abnormality by changing a method for projecting the projected pattern **90** onto the surface of projection **95**. In this example, the control device **130** is electrically connected to the illuminating device **30**. Upon detecting an abnormality, the control device **130** may send a control signal to the illuminating device **30** by wire or radio to change the method for projecting the projected pattern **90**. The change of the projecting method may be one or more of a change of the projected pattern, a change of the wavelength region of the illuminating light, and switching between glowing and blinking.

[0281] In the example shown in FIG. **17**, the movable body **80** is moved by the viewer **5** pushing the movable body **80**. The work device **84** carries out work on the surface of projection **95** while the movable body **80** is moving. The movable body **80** is not limited to the aforementioned work vehicle configured to draw a line on the surface of projection **95**. Further, the movable body **80** may move with the viewer **5** on board.

[0282] The movable body **80** may be a work vehicle configured to make a road or a sidewalk, may be a work vehicle configured to maintain a road or a sidewalk, may be a work vehicle configured to carry out farm work, or may be a work vehicle configured to plow fields. Examples of the movable body **80** configured to make or maintain a road or a sidewalk include a grader, an asphalt finisher, a road roller, a tire roller, a wheel loader, a truck mixer, a line-drawing vehicle, a snowplow, and a garbage truck. Examples of the movable body **80** configured to carry out farm work or plow fields include a rice transplanter, a reaper, a mower, a tractor, a chemical sprayer, and a cultivator. The movable body **80** may be a special-purpose vehicle or an industrial vehicle designated in ISO 5053-1.

[0283] As shown in FIG. **20**, the viewer **5** may operate the movable body **80** using a remote controller **87** while viewing the display device **102**. As mentioned above, the movable body **80** may be a train, an airplane, a ship, or, as shown in FIG. **21**, a drone. In the example shown in FIG. **21**, the movable body **80** as a drone may include a work device **84**. The work device **84** that is mounted on the movable body **80** as a drone may be a spray device.

[0284] The projected pattern **90** is not limited to a straight linear pattern. As mentioned above, the projected pattern **90** is able to be changed. FIGS. **22** and **23** show modifications of projected patterns **90** and display patterns **92**.

[0285] As shown in FIG. **22**, the projected pattern **90** may include a first linear pattern **91**A and a second linear pattern that intersect each other. The first linear pattern **91**A and the second linear pattern **91**B may be orthogonal to each other. The projected pattern **90** may be a cross mark. With a point of intersection of the first linear pattern **91**A and the second linear pattern **91**B, the projected pattern **90** may indicate an objective point of movement that should be finally reached or may indicate the center of a place in which the work should be carried out.

[0286] In the example shown in FIG. **22**, the display pattern **92** includes a first auxiliary pattern **93**A and a second auxiliary pattern **93**B. The first auxiliary pattern **93**A is located on an extension of the first linear pattern **91**A. A pair of the first auxiliary patterns **93**A extend out from both ends of the first linear pattern **91**A. The second auxiliary pattern **93**B is located on an extension of the second linear pattern **91**B. A pair of the second auxiliary patterns **93**B extend out from both ends of the second linear pattern **91**B. A combination of the projected pattern **90** and the display pattern **92** indicates a large cross mark. The display pattern **92** of the display pattern **92** may be combined with the projected pattern **90** to indicate a region in which the work should be carried out.

[0287] In the example shown in FIG. **23**, the projected pattern **90** is a linear pattern extending in a circle. The projected pattern **90** may indicate the center of a region in which the work should be carried out. Unlike in the example shown in FIG. **23**, the projected pattern **90** may be in the shape of a line extending in an ellipse, may be in the shape of a line extending along the contours of a triangle, may be in the shape of a line extending along the contours of a quadrangle, or may be in the shape of a line extending along the contours of a polygon such as a pentagon or a hexagon. The projected pattern **90** may be in the shape of a circle, may be in the shape of a triangle, may be in the shape of a quadrangle, or may be in the shape of a polygon such as a pentagon or a hexagon.

[0288] In the example shown in FIG. **23**, the display pattern **92** includes an auxiliary pattern **93** circumferentially surrounding the projected pattern **90**. The auxiliary pattern **93** may be adjacent to the projected pattern **90**. The auxiliary pattern **93** may be spaced from the projected pattern **90** as in the case of the illustrated example. The auxiliary pattern **93** spaced from the projected pattern **90** may be in the shape of a line. The auxiliary pattern **93** of the display pattern **92** may be combined with the projected pattern **90** to indicate a region in which the work should be carried out.

[0289] A center of gravity **93**Y of a region surrounded by an outer contour **93**X of the auxiliary pattern **93** may be in a position that is identical to that of at least either a center of gravity **90**Y of the projected pattern **90** or a center of gravity **90**Y of a region surrounded by an outer contour **90**X of the projected pattern **90**. In the example shown in FIG. **23**, the display pattern **92** includes auxiliary patterns **93** extending along two circles arranged concentrically with the projected pattern **90**. As is the case with the projected pattern **90**, each of the auxiliary patterns **93** may be in the shape of a line extending in an ellipse, may be in the shape of a line extending along the contours of a triangle, may be in the shape of a line extending along the contours of a quadrangle, or may be in the shape of a line extending along the contours of a polygon such as a pentagon or a hexagon.

[0290] FIG. **24** shows the display surface **103** of the display device **102**. The display device **102** displays an image taken by the imaging device **101**. The projected pattern **90** shown in FIG. **23** is projected in a range of imaging of the imaging device **101**. The display device **102** displays the auxiliary patterns **93** of the display pattern **92** over an image including the projected pattern **90**. The display device **102** occupies the reference pattern **97** over the image including the projected pattern **90**. The reference pattern **97** is a cross mark.

[0291] In the specific example shown in FIG. **24**, the surface of projection **95** onto which the projected pattern **90** is projected is a field where crops are grown. Assume that a spaying substance such an agricultural chemical or a fertilizer is sprayed onto a predetermined spray region of this field. In this assumption, the projected pattern **90** may indicate the center of the spray region. The auxiliary patterns **93** of the display pattern **92** may indicate a range of the spray region.

[0292] The reference pattern **97** may indicate, according to the orientation of a nozzle through which the spraying substance is ejected, a position onto which the spraying substance is sprayed. That is, the reference pattern **97** may indicate, according to the orientation of the nozzle, a scheduled position onto which the spraying substance is sprayed. In this example, the imaging device **101** may be attached to the nozzle. In this example, the reference pattern **97** may be generated by the control device **130** based on a state of the work device **84**.

[0293] The reference pattern **97** may include a first reference pattern **97**A and a second reference pattern **97**B. In the example shown in FIG. **25**, the first reference pattern **97**A is a cross mark that indicates a scheduled position of spraying. The second reference pattern **97**B is an arrow that indicates a direction in which the scheduled position of spraying moves. The direction of movement of the scheduled position of spraying as indicated by the second reference pattern **97**B may be identified by a process in the control device **130** based on operation information of the nozzle through which the spraying substance is ejected.

[0294] As mentioned above, the control device **130** detects the pattern **90** in the image displayed on the display device **102** and generates a display pattern **92** associated with the pattern thus detected. The display device **102** displays the display pattern **92** over the image. The viewing assist device **100** including such a control device **130** and the display device **102** is applicable to a pattern other than the projected pattern that is projected from the illuminating device **30**. For example, the viewing assist device **100** including the display device **102** and the control device **130** is also applicable to viewing of a pattern drawn with paint on a surface.

[0295] A display device **102** configured to display an image taken by an imaging device **101** including no optical filter **120** and a control device **130** may be combined with each other. Also in this example, a display pattern **92** can be displayed over the image by the control device **130** detecting a pattern from the image.

REFERENCE SIGNS LIST

[0296] D**1** first direction [0297] D**2** second direction [0298] D**3** third direction [0299] **5** viewer [0300] **10** projection system [0301] **30** illuminating device [0302] **31** emission end [0303] **40** light source [0304] **45** shaping optical system [0305] **46** first lens [0306] **47** second lens [0307] **48** third lens [0308] **50** diffraction optical element [0309] **55** elemental diffraction optical element [0310] **60** scanning device [0311] **70** casing [0312] **71** cylindrical portion [0313] **71***a* stepped portion [0314] **72** lid portion [0315] **73** spacing ring [0316] **74** battery [0317] **75** circuit [0318] **76** switch [0319] **80** movable body [0320] **81** windshield [0321] **82** partitioning member [0322] **84** work device [0323] **86** notification device [0324] **90** projected pattern [0325] **92** display pattern [0326] **93** auxiliary pattern [0327] **94** detection pattern [0328] **95** surface of projection [0329] **96** illuminated region [0330] **97** reference pattern [0331] **100** viewing assist device [0332] **101** imaging device [0333] **101***a* imaging element [0334] **102** display device [0335] **104** wearable tool [0336] **105** light-shielding wall portion [0337] **106** frame [0338] **106**A frame body [0339] **106**B holding portion [0340] **107** wearable tool body [0341] **108** contact lens body [0342] **120** optical filter

[0343] **121** substrate [0344] **122** dielectric multilayer film [0345] **122***a* low-refractive-index layer [0346] **122***b* high-refractive-index layer [0347] **130** control device

Claims

1. A projection system comprising: an illuminating device configured to emit illuminating light and project a projected pattern onto a surface of projection; and an optical filter configured such that an average transmittance of the optical filter in a wavelength region of the illuminating light is higher than an average transmittance of the optical filter in a visible light wavelength region other than the wavelength region of the illuminating light, wherein the wavelength region of the illuminating light is a wavelength region ranging from a wavelength that is 5 nm lower than a peak wavelength of the illuminating light to a wavelength that is 5 nm higher than the peak wavelength, and the peak wavelength of the illuminating light is a wavelength at which a maximum radiant flux of the illuminating light is attained.
2. (canceled)
3. The projection system according to claim 1, further comprising a wearable tool that a viewer of the projected pattern is able to wear, wherein the wearable tool includes the optical filter, and in a state where the viewer is wearing the wearable tool, the optical filter faces eyes of the viewer.
4. The projection system according to claim 3, wherein the wearable tool includes a light-shielding wall portion located around the optical filter, and in a state where the viewer is wearing the wearable tool, the light-shielding wall portion is located between the optical filter and the viewer.
5. The projection system according to claim 1, wherein the optical filter constitutes a windshield of a movable body.
6. The projection system according to claim 1, further comprising an imaging device including the optical filter.
7. The projection system according to claim 6, further comprising a display device electrically connected to the imaging device, wherein the display device displays an image taken by the imaging device.
8. The projection system according to claim 7, wherein the display device includes a wearable tool that a viewer is able to wear and a display element held by the wearable tool and configured to display the image, and in a state where the viewer is wearing the wearable tool, the display element faces eyes of the viewer.
9. The projection system according to claim 8, wherein a total transmittance of the display element is 1% or higher.
10. The projection system according to claim 7, further comprising a control device electrically connected to the imaging device and the display device, wherein the control device detects the projected pattern in the image displayed on the display device and generates a display pattern associated with the projected pattern thus detected, and the display device displays the display pattern over the image.
11. The projection system according to claim 10, wherein the projected pattern includes a linear pattern, and the display pattern includes a linear auxiliary pattern extending as an extension of the projected pattern.
12. The projection system according to claim 10, wherein the display pattern includes an auxiliary pattern circumferentially surrounding the projected pattern.
13. The projection system according to claim 10, wherein the display pattern includes a detection pattern overlapping the projected pattern thus detected.
14. The projection system according to claim 7, wherein the imaging device is able to move relative to the surface of projection, and the display device displays, over the image, a reference pattern indicating a predetermined position, a predetermined direction, or a predetermined range within a range that is imaged by the imaging device.

15. The projection system according to claim 14, further comprising a movable body that is able to move relative to the surface of projection, wherein the imaging device is held by the movable body.
16. (canceled)
17. The projection system according to claim 10, wherein the display device displays, over the image, a reference pattern indicating a predetermined position, a predetermined direction, or a predetermined range within a range that is imaged by the imaging device, the control device evaluates a positional relationship between the reference pattern and at least either the projected pattern thus detected or the display pattern thus generated, and in a case where the control device determines that there is an abnormality in the positional relationship, the abnormality is notified.
18-19. (canceled)
20. The projection system according to claim 1, wherein an average transmittance of the optical filter in a visible light wavelength region other than a wavelength region of 30 nm centered at the peak wavelength of the illuminating light is 1% or lower.
21. (canceled)
22. The projection system according to claim 1, wherein an illuminance LX (lx) that is a maximum value of an illuminance of the projected pattern projected onto the surface of projection, an illuminance LY (lx) attributed to ambient light at a position on the surface of projection at which the illuminance LX is attained, an average transmittance TX (%) of the optical filter in the wavelength region of the illuminating light, and an average transmittance TY (%) of the optical filter in a visible light wavelength region other than a wavelength region of 30 nm centered at the peak wavelength of the illuminating light satisfy 0.001≤(LX.Math.TX)/(LY.Math.TY).
23. The projection system according to any one of claim 1, wherein the illuminating device includes a light source configured to emit coherent light as the illuminating light and a diffraction optical element configured to diffract the coherent light.
24. A viewing assist device configured to assist viewing of a projected pattern that is projected onto a surface of projection with use of illuminating light emitted from an illuminating device, the viewing assist device comprising an optical filter configured such that an average transmittance of the optical filter in a wavelength region of the illuminating light is higher than an average transmittance of the optical filter in a visible light wavelength region other than the wavelength region of the illuminating light, wherein the wavelength region of the illuminating light is a wavelength region ranging from a wavelength that is 5 nm lower than a peak wavelength of the illuminating light to a wavelength that is 5 nm higher than the peak wavelength, and the peak wavelength of the illuminating light is a wavelength at which a maximum radiant flux of the illuminating light is attained.
25-28. (canceled)
29. The viewing assist device according to claim 1, further comprising a control device electrically connected to the imaging device, wherein the control device detects the projected pattern in the image displayed on the imaging device and generates a display pattern associated with the projected pattern thus detected.