

DESCRIPTION

TITLE OF THE INVENTION: DEVICE FOR THE AERIAL AND VIRTUAL PROJECTION OF AN AUTOSTEREOSCOPIC IMAGE OR OF A SEQUENCE OF AUTOSTEREOSCOPIC IMAGES, IN PARTICULAR FOR USE IN A MOTOR VEHICLE

Technical field of the invention

The invention relates to a device for the aerial and virtual projection of an autostereoscopic image or of a sequence of autostereoscopic images. The invention is particularly intended for use in the automotive field, yet without being exclusively intended for this use.

Technological background

A device for the aerial and virtual projection of an object is a device that allows an image of the object to be projected in front of a window made in a housing and that gives the observer the illusion of a three-dimensional object floating in space.

Such a device is known for projecting real objects. Such a device typically comprises a housing (which may or may not be opaque) that includes an opening intended to form an observation window for the virtual image, an optical system, in general a lens, a Fresnel lens, a set of lenses or a concave mirror, and an object arranged at a distance from the optical system that is configured to orient the image of the object towards the observation window.

For example, document US 6817716 describes such a device comprising a lower compartment in which a real object is illuminated by a light source, an upper compartment comprising an observation window arranged on the front face, a concave mirror and a semi-transparent flat mirror inclined at 45 degrees on the optical axis of the concave mirror on which the observation window is centered, with said semi-transparent mirror being arranged between the observation window

and the concave mirror in line with the real object. Thus, the illuminated object partially reflects in the semi-transparent mirror inclined at 45 degrees towards the concave mirror, which returns the light rays through the semi-transparent mirror towards the observation window. The observer then has the impression of seeing
5 the real object floating in front of the observation window.

The applicant has also already proposed, in document WO 2018/167410, a device for projecting an autostereoscopic image.

This device comprises a housing comprising a front wall, a rear wall, connected to each other by an upper wall and a lower wall, with said front wall
10 comprising an opening forming an observation window for an aerial and virtual image of said digital autostereoscopic image.

The device also comprises an optical system comprising at least one concave spherical mirror having an optical axis, a focal length F , a center of a radius of curvature C located on the optical axis, with the optical system being arranged in
15 the housing such that it can orient at least some of the received incident light towards the observation window in order to form an aerial and virtual image of the digital autostereoscopic image therein.

The autostereoscopic image is projected by an autostereoscopic image display screen with N viewpoints superposed by an array of cylindrical lenticules
20 forming an optical component for selecting the viewpoints of the digital autostereoscopic image to be projected, housed in the housing opposite the spherical mirror at a distance that is substantially equal to twice the focal length F , and spaced apart from the optical axis of the spherical mirror, perpendicular to this optical axis by a distance that is at least equal to the half-height of the display
25 screen, with the height being defined along the axis perpendicular to the optical axis.

This device advantageously allows autostereoscopic images to be viewed that appear to float in space.

However, the inventors have attempted to improve this device, in particular for automotive applications faced with spatial requirement and costs constraints.

Furthermore, the inventors have attempted to improve the quality of the autostereoscopic image perceived by the observer.

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Aims of the invention

The aim of the invention is to provide a system for the aerial and virtual projection of an autostereoscopic image that overcomes at least some of the disadvantages of the known solutions.

10 The invention also aims to provide, in at least one embodiment, such a projection system that hides the components of the system from the observer.

The invention also aims to provide, in at least one embodiment, such a projection system, the components of which are arranged below the line of sight of the observer towards the viewing area of the aerial and virtual image.

15 The invention also aims to provide, in at least one embodiment, such a system that can be seamlessly integrated into a motor vehicle for projecting driving information intended for the driver.

The invention also aims to provide, in at least one embodiment, such a projection system that is compact and is made up of a limited number of components.

20 The invention also aims to provide, in at least one embodiment, such a projection system that provides various configurations in order to adapt to various integration and usage constraints.

25 Finally, the invention aims to provide a device for displaying driving information for a driver of a motor vehicle comprising a projection system according to the invention.

Disclosure of the invention

To this end, the invention relates to a system for the aerial and virtual

projection of an autostereoscopic image intended for an observer whose eyes are positioned within a predetermined three-dimensional space, called eyebox.

The system according to the invention is characterized in that it comprises:

- 5 - an optical device comprising at least one convergent optical component acting like a concave mirror having a radius of curvature R and a focal length F , said optical device being arranged relative to said eyebox so as to be able to direct the light rays it receives towards a viewing window observable from said eyebox;
- 10 - an autostereoscopic display screen arranged relative to said optical device such that the light rays that it emits can reach said viewing window, after reflecting on said convergent optical component, and having travelled a distance d equal to twice the focal length F , said screen comprising:
 - 15 ○ a matrix of pixels of N rows and M columns, each pixel being made up of a plurality of sub-pixels of different colors;
 - a lenticular array superposing said matrix of pixels, and having a pitch P determined from a pitch P' , called nominal pitch, of an autostereoscopic screen, called nominal screen, having usage features identical to those of the screen of the system and
 - 20 intended to be observed by direct viewing at a distance corresponding to the usage distance of said screen of the system, using the formula $P = P' \cdot (1 - C / (S \cdot M))$, where C is the number of portions of viewpoints simultaneously visible from said usage distance inside said eyebox, when said nominal screen of pitch
 - 25 P' is arranged in said projection system instead of said screen, and S is the number of different viewpoints addressed by each pixel of said matrix.

30 The system according to the invention thus implements a specific and specially designed autostereoscopic screen designed with this sole purpose, in order to allow the virtual reflection of an autostereoscopic image reflected by a convergent optical component to be observed. Such a convergent optical

component is, for example, a concave mirror or a holographic optic. Such a convergent optical component acts like a concave mirror. Throughout the remainder of the description, the term concave mirror is mainly used for the sake of readability, but it is understood that this concave mirror can be replaced by a
 5 holographic optic without modifying the technical effects of the invention.

In particular, an autostereoscopic screen designed for direct observation is not suitable for use within a device for virtualizing the screen implementing a reflection of the screen on a concave mirror.

Indeed, such a device for virtualizing the screen must allow all the targeted
 10 features to be found in the main lobe of the screen (which designates the space in front of the screen where the different viewpoints of the autostereoscopic image follow one another at a preferred distance for observing the screen, called flat tint distance and corresponding to the distance at which each eye of the observer perceives only one point of view of the image over the entire surface of the screen),
 15 namely: the number of viewpoints, the flat tint distance, and the distribution of viewpoints over the matrix of pixels. However, experience has shown that a concave mirror alters all these features so that an autostereoscopic screen designed for direct viewing is hardly suitable or is not suitable for use in a device implementing a concave mirror.

20 When a screen is positioned at twice the focal length of a concave mirror or in front of any other optical system acting in the same way, a holographic optical element, for example, whose working surface would be at least equal to that of the screen, then a reflected image of the screen is obtained in return that is the same size but is inverted (scale -1).

25 The deformations induced by the concave mirror require the introduction of new rules for defining the parameters of the lenticular array, that differ from those of a direct viewing array. In order for the virtual duplicate reflected from the screen to have the desired autostereoscopic properties, the features of the lenticular array of the screen need to be modified. The presence of a concave mirror transforms all

the previously described parameters. In order to maintain the desired features, the pitch of the array must be decreased according to proportions that are such that the screen would no longer be observable by direct viewing. The inventors have succeeded in determining the level of correction of the pitch to be applied in order
 5 to allow this reflected observation in a concave mirror.

This reduction in the pitch is obtained, according to the invention, based on the pitch P' of an autostereoscopic screen, called nominal screen, with usage features identical to those of the screen of the system but intended to be observed by direct viewing at a distance corresponding to the usage distance of said screen
 10 of the system, using the formula $P = P' \cdot (1 - C/S.M)$, where C is the number of portions of viewpoints simultaneously visible from said usage distance inside the eyebox, when said nominal screen of pitch P' is arranged in said projection system instead of said screen, S is the number of different viewpoints of the image addressed by each pixel of said matrix of pixels and M is the number of pixels per
 15 row of the matrix of pixels.

By way of an example, for addressing the sub-pixel based on a matrix of pixels where each pixel comprises 3 different colored sub-pixels, then S equals 3. Thus, the pitch P is obtained using the formula $P = P' \cdot (1 - C/(3.M))$.

If the same matrix is used for integer pixel addressing, then S equals 1 and
 20 the pitch P is obtained using the formula $P = P' \cdot (1 - C/M)$.

Throughout the remainder of the description and for the sake of readability, addressing the sub-pixel and a matrix where each pixel is formed by 3 sub-pixels is considered, with it being understood that the technical teaching that is provided applies, *mutatis mutandis*, to integer pixel addressing and/or to matrices comprising
 25 other than 3 sub-pixels.

By way of an example, if a color chart displayed on a nominal autostereoscopic screen is reflected in a concave mirror, the image reflected back from this color chart exhibits, for the initially selected flat tint, a number of color bars corresponding to a projected pitch that has reached at least two or three lenses

for the entire array relative to the screen.

For example, for a screen with 5 viewpoints, if the observer perceives 5 color bars on the screen, at any distance from the screen, this means that they have deviated from the flat tint distance to the extent that the projected pitch has increased or decreased by 5 sub-pixels, i.e., the pitch of a lens. If the observer
 5 perceives 10 color bars, this means that the projected pitch has increased or decreased by 10 sub-pixels, or two lenses. If the screen displays a single color, this means that the observer is at the flat tint distance.

Insofar as it is possible to know the pitch of the lenticular array of a nominal
 10 screen very accurately, for example, to the nearest 100th micron, it is then possible to correct the effect of the concave mirror on the optical path that connects the surface of the actual screen to the eyes of the user through the actual virtual conjugate image, by machining a new lenticular array at the corrected pitch.

It can be seen that this amounts to creating a flat tint for direct viewing
 15 outside the projection device at a very short distance from the screen. This therefore amounts to significantly reducing the pitch of the lenticular array relative to use for direct viewing.

If a nominal screen with 5 viewpoints placed in the projection device allows
 12 color bars to be viewed at the desired flat tint distance of 1 m, for example
 20 (assuming that the screen displays 5 distinct colors, with each color corresponding to a viewpoint), and since the pitch of a lens corresponds to 5 direct viewing colors, 12 color bars reflected in the concave mirror represent the 12/5^{ths} of the pitch of the lenses. The lenticular array needs to be reduced by this value in order to adapt it to the device according to the invention and to divide it by the total number of lenses
 25 in order to compute the exact incidence on the pitch that will be applied to the machining of the lenticular array of the screen intended to be arranged in the projection device.

This allows a system to be obtained whose autostereoscopic image virtualized and reflected by the mirror allows all the features to be found that are

provided in the central lobe.

For the first time, it is then possible to simply determine the correction of the pitch to be applied to a nominal autostereoscopic screen, for its integration into a device implementing a concave mirror, by knowing the pitch of the nominal
 5 screen and by determining the number of portions of viewpoints simultaneously visible from said usage distance inside said eyebox, when this screen is housed in the device according to the invention.

As previously seen, this determination of the number of simultaneously visible portions of viewpoints can be facilitated by displaying a color chart on the
 10 screen, thereby simultaneously counting, from said eyebox corresponding to the screen usage distance, the number of visible color bands.

Advantageously and according to the invention, the system further comprises:

- 15 - a housing comprising an opaque front wall extending opposite said observer and an opaque upper wall connected to said front wall and extending parallel to a plane, called horizon plane, said upper wall being provided with an upper opening;
- 20 - a front face mirror inclined at an angle α relative to the horizontal while at least partially extending above said upper opening, said mirror having a reflective surface oriented towards said observer;
- 25 - said convergent optical component is arranged at the base of the front face mirror, facing said opening and oriented such that its reflective surface is oriented towards said inclined mirror extending above said upper opening, said convergent optical component having an optical axis forming an angle δ' relative to the horizontal;
- said autostereoscopic display screen is inclined at an angle θ relative to the vertical, arranged below the opaque upper wall at a distance from the middle of the image of the convergent optical component formed by the inclined mirror that is equal to the radius of curvature of said convergent

optical component;

- said angles α , δ' and θ being connected by the following relations:

$$\delta' = 2.\delta, \text{ where } \delta = 45^\circ - \alpha;$$

5 $\theta = \beta$, where β is the angle formed, relative to the horizontal, by the gaze direction of the observer, from the eyebox, towards said viewing window and directed towards the center of the reflection of the concave mirror.

Thus, and according to this advantageous variant, the system comprises an inclined flat front face mirror that at least partially extends above an opening
10 provided in a wall through which rays reflected by a convergent optical component can pass in order to reflect in the flat front face mirror and form, in the vicinity of a predetermined viewing area, a virtual image of the image that is the source of its rays.

Furthermore, the volume occupied by the system is divided into two parts,
15 each on either side of a median plane, called horizon plane.

This horizon plane is defined by the upper wall of the system, which is preferably made of an opaque material. This upper wall is perforated with an opening and the mirror is inclined at an angle α relative to the horizontal that at least partially extends above this opening.

20 According to one embodiment of the invention, the front face mirror passes through the upper opening so as to delimit a mirror portion extending above the horizon plane visible to the observer and a portion of the mirror extending below the horizon plane hidden by said opaque walls of the housing.

According to the invention, the top of this mirror approaches the observer
25 and the bottom of the mirror moves away from the observer. Other inclines are possible depending on the uses and integration constraints.

The emergent portion of the mirror is, for example, the same size as the portion hidden below the horizon plane.

The concave mirror (also referred to using the term convergent optical component) is located at the base of the inclined mirror, and is oriented such that the concave and reflective face is oriented upwards, facing the upper opening made in the upper wall.

- 5 Thus, the concave mirror reflects in the portion of the inclined flat front face mirror that extends above the upper opening and forms a vertical image therein as if the concave mirror was placed vertically behind the latter.

- 10 The autostereoscopic screen is located, under the upper wall, with the back facing the observer, at a distance equal to the radius of curvature of the concave mirror starting from the middle of the image thereof formed by the inclined front face mirror. The upper edge of the screen is in the vicinity of the upper wall, immediately below the upper wall, making it invisible to the observer. This screen is inclined at an angle θ relative to the vertical.

- 15 The image displayed by this screen is identically visible on the other side of the horizon plane, in the form of a conjugate image at a scale of -1. Indeed, all the light rays emanating from the screen and touching the image of the concave mirror are refocused at an equivalent distance above the horizon plane in order to form a virtual conjugate image of the screen yet that is real in the optical sense, visible by the observer placed in front of the device.

- 20 The light rays originating from the screen are reflected downwards by the portion of the inclined flat front face mirror extending below the horizon plane, and then they upwardly reflect on the concave mirror and are reflected a second time by the visible portion of the inclined flat front face mirror, which directs them towards the eyes of the observer. The concave curvature of the mirror directs the rays such that those originating from a given point of the screen appear to intersect on the counterpart of the conjugate image of the screen above the plane of the horizon, creating the illusion that they actually emanate from this location. For the observer, whose eyes are located on their trajectory, these rays together form an image similar to that of the screen and to what it displays, which remains directly
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invisible under the horizon plane.

The autostereoscopic screen is provided with a specific lenticular array, as previously described, such that the image that can be seen by the observer retains the expected autostereoscopic parameters after being reflected by the concave mirror. The pitch of the lenticular array is adjusted relative to that of a screen observed directly, without being reflected by a concave mirror, in order to compensate for the change in its apparent pitch after being reflected in a concave mirror or even after being transmitted through a convergent optical component, whether it is a lens with the same radius and the same focal length or is even a holographic optical component. More specifically, the conical perspective resulting from reflecting or transmitting through a convergent optical component modifies the perceived pitch. By virtue of the previous correction of the pitch, the device allows a three-dimensional image to be displayed above the horizon plane, like that of an autostereoscopic screen that is observed directly.

From the eyebox, and in the vicinity of the viewing window, the observer perceives an aerial and virtual relief image, without viewing the convergent optical component or the screen located below the horizon plane.

Advantageously and according to the invention, said angle α is 36° , said angle β is 20° , said angle δ' is 18° and said angle θ is 20° .

According to this advantageous variant, the angles are determined so that an observer whose gaze axis towards the projection area forms an angle of 20° relative to the horizontal can perceive the autostereoscopic image with a mirror inclined at 36° relative to the horizontal, which corresponds to the standard incline of a windscreen of a motor vehicle.

A device according to this variant therefore can be integrated into a motor vehicle to ensure the aerial and virtual projection of an autostereoscopic image intended for a driver.

If applicable, the inclined mirror is formed by a windscreen of a motor

vehicle and said opaque upper wall of said housing is formed by a portion of the frontal area of the vehicle.

Of course, other applications can be targeted by a system according to the invention and the angle values are not set and can vary depending on the usage
5 conditions and the applications for the purpose of maintaining the same result.

The invention also relates to a device for displaying driving information of a motor vehicle comprising a windscreen, a steering wheel and a front dashboard extending between the windscreen and the steering wheel, characterized in that said display device comprises a projection system according to the invention in which
10 said inclined mirror is formed by said windscreen, said opaque wall is formed by said front dashboard that includes an opening for forming said upper projection opening of said autostereoscopic image, with said convergent optical component and said autostereoscopic screen being housed under the front dashboard, such that a driver of the vehicle sitting in front of said windscreen can view driving
15 information by means of the aerial and virtual projection of autostereoscopic images displayed on said display screen in a predetermined projection area extending above said front dashboard.

Thus, and according to the invention, the frontal area of the motor vehicle acts as an upper wall and extends along the horizon plane and the windscreen acts
20 (under certain conditions such as the angle relative to the vertical, the shape and any surface treatments) as an inclined front face mirror. The frontal area of a motor vehicle is the substantially flat space located between the dashboard and the windscreen of the vehicle. This space therefore can usefully act as an opaque upper portion extending along the horizon plane of the system according to the invention.
25 In the event that the curvature of the windscreen would be even and homogeneous enough, it could supplement the concave curvature of the main mirror that will need to be adjusted to take this into account.

The rays emitted by the autostereoscopic screen are reflected by the portion of the windscreen located below the opening in the dashboard. The screen needs to

be slightly inclined so that its conjugate image is orthogonal to the gaze axis and so as to avoid trapezium deformations. The rays are then reflected downwards towards the concave mirror and then towards the portion of the windscreen above the opening in the dashboard, where they are directed towards the eyebox.

5 According to an advantageous variant, the windscreen is inclined at 36° relative to the horizontal and the concave mirror is inclined at 20° relative to the vertical in order to provide a vertical image thereof seen as a reflection in the windscreen, for an observer whose gaze axis forms an angle of the order of 20° with the desired projection area of the aerial and virtual image. The important parameter
10 is the practical verticality of the image of the concave mirror in the reflective portion of the windscreen. Small changes in the position and the angle of all the components each restore the position, the size and the incline of the virtual image of the screen, immediately above the horizon plane.

Thus, according to this alternative embodiment, the projection system
15 allows information from the dashboard (for example, speedometers, navigation information, GPS, etc.) to be projected towards the eyes of the observer by displaying it on the autostereoscopic screen. This information is then projected by the windscreen and the concave mirror towards the eyes of the driver. The system according to this variant benefits from the presence of the windscreen and uses its
20 lower, generally opaque, part in order to establish a front face mirror. The windscreen may need to be treated in order to provide it with this reflective functionality.

Advantageously and according to the invention, the concave mirror has a radius of curvature of 300 mm and a focal length of 150 mm.

25 Of course, other mirrors can be used without undermining the principle of the invention.

The invention also relates to a method for producing a system for the aerial and virtual projection of an autostereoscopic image intended for an observer whose eyes are positioned within a predetermined three-dimensional space, called eyebox,

said method comprises the following steps of:

- 5 - selecting an autostereoscopic screen, called nominal screen, having predetermined usage features and being formed by a matrix of pixels of N rows and M columns and being superposed by a lenticular array with a predetermined pitch P' ;
- 10 - arranging said nominal screen in a projection system comprising a convergent optical component that acts like a concave mirror of radius R and focal length F , said convergent optical component being arranged relative to said eyebox so as to be able to direct the light rays it receives towards a viewing window observable from said eyebox, said nominal screen being arranged relative to the convergent optical component so that the light rays that it emits can reach said viewing window, after reflecting on said convergent optical component, with the light rays having travelled a distance d equal to twice the focal length F ;
- 15 - displaying a color chart on said nominal autostereoscopic screen;
- computing the number C of colors simultaneously observed from said usage distance inside said eyebox;
- 20 - manufacturing an autostereoscopic screen, called dedicated screen, having the same predetermined usage features as those of said nominal screen and a lenticular array with a pitch P computed by the formula $P = P' \cdot (1 - C / (S \cdot M))$, where S is the number of different viewpoints addressed by each pixel of said matrix;
- replacing said nominal screen with said dedicated screen.

25 The advantages and technical effects of the projection device according to the invention apply, *mutatis mutandis*, to the method for developing an aerial and virtual projection system according to the invention.

30 The invention also relates to a system for the aerial and virtual projection of an autostereoscopic image and a device for displaying driving information of a motor vehicle, which are characterized, in combination, by all or some of the features mentioned above or hereafter.

List of figures

Further aims, features and advantages of the invention will become apparent upon reading the following description, which is provided solely by way of a non-limiting example and which refers to the appended figures, in which:

- 5 – figure 1 is a schematic view of the projection system according to a first embodiment of the invention;
- figure 2 is a view of the device for displaying driving information of a motor vehicle according to one embodiment of the invention;
- 10 – figure 3 is a schematic view of an autostereoscopic screen of a projection system according to one embodiment of the invention.

Detailed description of an embodiment of the invention

Throughout the figures, the scales and proportions are not strictly followed for the sake of illustration and clarity.

15 Identical, similar or analogous elements are designated using the same references throughout all the figures.

The embodiments described with reference to the figures relate to displaying an autostereoscopic image.

20 Figure 1 schematically illustrates a system according to one embodiment of the invention that is intended to be integrated inside a motor vehicle, as is schematically shown in figure 2.

In figure 1 the dashed lines represent the paths of the light rays and the conjugate images of the image and the concave mirror.

25 The system comprises an opaque housing 30 comprising an upper wall 20 provided with an opening 22, through which an inclined front face mirror 10 extends.

This front face mirror 10 is inclined at an angle α relative to the horizontal. The mirror 10 has a reflective surface oriented towards the observer. This observer is located to the right of the device and is looking towards a predetermined

projection area 18.

The front face mirror 10 defines a mirror portion extending above the horizon plane visible to the observer and a portion of the mirror extending below the horizon plane hidden by the housing 30.

5 The system also comprises a concave mirror 14 arranged at the base of the front face mirror 10, facing the opening 22 and oriented such that its concave and reflective surface is oriented towards the inclined front face mirror 10.

10 This concave mirror has, for example, a radius of 300 mm, a focal length of 150 mm for a useful area of 150 mm, that is, F/1. The mirror has an optical axis forming an angle δ' relative to the horizontal.

The system also comprises a display screen 16 for displaying an autostereoscopic image inclined at an angle θ relative to the vertical.

15 The screen is arranged below the opaque upper wall at a distance from the middle of the image of the concave mirror formed by the inclined mirror that is equal to the radius of curvature of the concave mirror 14.

The incline of the screen 16 must allow the emitted light rays to reach the inclined flat mirror 10 so that these rays can be reflected downwards towards the concave mirror 14.

20 This screen is equipped with a lenticular array whose pitch is determined in order to be able to compensate for its apparent change after being reflected by the concave mirror.

25 Figure 3 schematically illustrates an autostereoscopic screen 16 comprising a matrix of pixels 16a arranged in rows and columns, with each pixel being made up of a plurality of sub-pixels with different colors each assigned to a viewpoint of the autostereoscopic image to be displayed. The screen also comprises a lenticular array 16b that superposes the matrix 16a. Each lens is inclined at a non-zero angle relative to the direction of the columns of the matrix (for example, 18°). According to other embodiments, it is also possible to use a vertical array.

As previously indicated, nothing precludes the use of pixel addressing of the viewpoints of the image. Throughout the remainder of the description, sub-pixel addressing of pixels each formed by three sub-pixels with different colors (i.e., S equals 3) is considered.

- 5 The pitch P of the array 16b of the screen 16 is determined based on the pitch P' , called nominal pitch, of an autostereoscopic screen, called nominal screen, with usage features identical to those of the screen of the system and intended to be observed by direct viewing at a distance corresponding to the usage distance of the screen of the system, using the formula $P = P' \cdot (1 - C/3 \cdot M)$, where C is the number
10 of portions of viewpoints simultaneously visible from the usage distance inside said eyebox, when said nominal screen of pitch P' is arranged in said projection system instead of said screen, and M is the horizontal resolution of the matrix of pixels.

- For example, considering a 5-inch screen with 5 viewpoints and resolution of 800×480 . This screen is placed 300 mm from the concave mirror in a square
15 format with 150 mm sides, with a focal length of 150 mm and a radius of curvature of 300 mm. Once placed in the system, the observer views 12 color bars (assuming that one color per viewpoint is displayed on the screen) from the eyebox. With the pitch of a lens corresponding to 5 direct viewing colors, 12 color bars reflected in the concave mirror represent the $12/5^{\text{th}}$ of the pitch of the lenses.

- 20 Insofar as one image viewpoint is displayed per sub-pixel, the number of lenses of the array of the considered screen is equal to $(800 \text{ pixels} \times 3)/5$, i.e., 480 lenses.

The total pitch correction is therefore equal to $12/5 = 2.4$ lenses.

This corresponds to a lens correction equal to $2.4/480 = 0.005$.

- 25 In other words, the pitch of the lenses therefore must be reduced by 0.5%.

If the known pitch P' of a lens is 0.270 mm, the necessary pitch correction amounts to removing 0.00135 mm per lens.

Although this value of 1.35 microns appears relatively small, its incidence

is actually considerable for optimal observation of the autostereoscopic image reflected by the concave mirror. This correction is determinant in order to be able to exploit an autostereoscopic screen reflecting in a concave mirror.

In the embodiment of figure 1, the angle α is 36° , the angle β is 20° , the angle δ' is 18° , the angle δ is 9° and the angle θ is 20° .

Figure 2 schematically illustrates the system of figure 1 integrated in a vehicle in order to form a device for displaying driving information of a motor vehicle comprising a windscreen 100, a steering wheel 110, and a front dashboard 200 extending between the windscreen 100 and the steering wheel 110.

The windscreen 100 forms the inclined mirror of the projection system and the front dashboard 200 forms the upper opaque wall of the projection system.

This front dashboard 200 comprises an opening 220 that forms the opening through which the light rays projected by the concave mirror (not shown in figure 2) reflect in the windscreen 100.

The windscreen 100 extends over the opening in order to receive the light rays projected by the concave mirror therein.

Furthermore, the autostereoscopic screen (not shown in the figure) must be inclined so that the rays emitted thereby can reflect in the windscreen.

By way of an example, the windscreen has an incline of 36° relative to the horizontal ($\alpha = 36^\circ$), the concave mirror has an optical axis with an incline of 18° relative to the horizontal and the autostereoscopic screen has an incline of 20° relative to the vertical ($\theta = 20^\circ$), such that a driver whose gaze is at an angle of 20° relative to the horizontal ($\beta = 20^\circ$) can view the image of the screen in the vicinity of the predetermined viewing area that extends above the front face of the vehicle.

A person skilled in the art easily understands that the autostereoscopic screen and the concave mirror of the projection system are housed in a housing arranged under the front dashboard 200 according to the configuration described with reference to figure 1.

Thus, the driver of the vehicle can view driving information, which is projected from the autostereoscopic display screen towards a predetermined projection area that extends above the front dashboard 200, between the windscreen 100 and the driver.

- 5 The system according to the invention also can be modified in order to adapt to certain usage constraints. For example, it is possible to deviate from the theoretical values of the angles mentioned in the document or to arrange the screen at a distance different from the theoretical distance of the concave mirror.

- 10 For example, if the distance from the screen to the center of the reflection of the concave mirror is less than or greater than twice the focal length of the concave mirror, the system can still allow an autostereoscopic image to be viewed, but the actual virtual image will then be closer (or farther away) from the observer, by being expanded (or contracted).

- 15 It is also possible to voluntarily change the value of θ , by accepting to encounter small trapezium deformations in the image, in order to correct the impression of verticality of the image on the screen in order for objects to be displayed with an orientation that is consistent with the surface of the dashboard, for example. Thus, it is possible to select an angle θ of 12° instead of the theoretical angle of 20° for some applications.

CLAIMS

1. A system for the aerial and virtual projection of an autostereoscopic image intended for an observer whose eyes are positioned within a predetermined three-dimensional space, called eyebox, said system being characterized in that it comprises:
 - an optical device comprising at least one convergent optical component (14) acting like a concave mirror having a radius of curvature R and a focal length F , said optical device being arranged relative to said eyebox so as to be able to direct the light rays it receives towards a viewing window observable from said eyebox;
 - an autostereoscopic display screen (16) arranged relative to said optical device such that the light rays that it emits can reach said viewing window, after reflecting on said convergent optical component (14), and having travelled a distance d equal to twice the focal length F , said screen comprising:
 - o a matrix of pixels of N rows and M columns, each pixel being made up of a plurality of sub-pixels of different colors;
 - o a lenticular array superposing said matrix of pixels, and having a pitch P determined from a pitch P' , called nominal pitch, of an autostereoscopic screen, called nominal screen, having usage features identical to those of the screen of the system and intended to be observed by direct viewing at a distance corresponding to the usage distance of said screen of the system, using the formula $P = P' \cdot (1 - C / (S \cdot M))$, where C is the number of portions of viewpoints simultaneously visible from said usage distance inside said eyebox, when said nominal screen of pitch P' is arranged in said projection system instead of said screen, and S is the number of different viewpoints

addressed by each pixel of said matrix.

2. The system according to claim 1, characterized in that it further comprises:

- a housing (30) comprising an opaque front wall (20) extending opposite said observer and an opaque upper wall connected to said front wall and extending parallel to a plane, called horizon plane, said upper wall being provided with an upper opening (22);
- a front face mirror (10) inclined at an angle α relative to the horizontal while at least partially extending above said upper opening (22), said front face mirror having a reflective surface oriented towards said observer;

and in that:

- said convergent optical component (14) is arranged at the base of the front face mirror, facing said opening (22) and oriented such that its reflective surface is oriented towards said inclined front face mirror (10) extending above said upper opening, said convergent optical component having an optical axis forming an angle δ' relative to the horizontal;
- said autostereoscopic display screen (16) is inclined at an angle θ relative to the vertical, arranged below the opaque upper wall (20) at a distance from the middle of the image of the convergent optical component formed by the inclined front face mirror that is equal to the radius of curvature of said concave mirror;
- said angles α , δ' and θ being connected by the following relations:
 - $\delta' = 2.\delta$, where $\delta = 45^\circ - \alpha$;
 - $\theta = \beta$, where β is the angle formed, relative to the horizontal, by the gaze direction of the observer, from the eyebox, towards said viewing window and directed towards the center of the reflection of the convergent optical component.

3. The system according to claim 2, characterized in that said front face mirror

(10) inclined at an angle α relative to the horizontal passes through said upper opening (22) so as to delimit a mirror portion extending above the horizon plane visible to the observer and a portion of the mirror extending below the horizon plane hidden by said opaque walls of the housing.

- 5 **4.** The projection system according to any of claims 2 or 3, characterized in that said angle α is 36° , said angle β is 20° , said angle δ' is 18° and said angle θ is 20° .
- 5.** The projection system according to any of claims 1 to 4, characterized in that said convergent optical component is a concave mirror or a holographic optic.
- 10 **6.** The projection system according to claim 5, characterized in that said convergent optical component is a concave mirror (14) having a radius of curvature of 300 mm and a focal length of 150 mm.
- 7.** A device for displaying driving information of a motor vehicle comprising a windscreen (100), a steering wheel (110) and a front dashboard (200) extending

15 between the windscreen (100) and the steering wheel (110), characterized in that said display device comprises a projection system according to any of claims 2 to 4, wherein said inclined front face mirror is formed by said windscreen, said opaque wall is formed by said front dashboard that includes an opening (220) for forming said upper projection opening of said

20 autostereoscopic image, with said convergent optical component and said autostereoscopic screen being housed under the front dashboard, such that a driver of the vehicle sitting in front of said windscreen can view driving information by means of the aerial and virtual projection of autostereoscopic images displayed on said display screen in a predetermined projection area

25 extending above said front dashboard.
- 8.** A method for producing a system for the aerial and virtual projection of an autostereoscopic image intended for an observer whose eyes are positioned within a predetermined three-dimensional space, called eyebox, said method comprises the following steps of:

30 - selecting an autostereoscopic screen, called nominal screen, having predetermined usage features and being formed by a matrix of pixels

- of N rows and M columns and being superposed by a lenticular array with a predetermined pitch P' ;
- arranging said nominal screen in a projection system comprising a convergent optical component that acts like a concave mirror of radius R and focal length F , said convergent optical component being arranged relative to said eyebox so as to be able to direct the light rays it receives towards a viewing window observable from said eyebox, said nominal screen being arranged relative to the convergent optical component so that the light rays that it emits can reach said viewing window, after reflecting on said convergent optical component, with the light rays having travelled a distance d equal to twice the focal length F ;
 - displaying a color chart on said nominal autostereoscopic screen;
 - computing the number C of colors simultaneously observed from said usage distance inside said eyebox;
 - manufacturing an autostereoscopic screen, called dedicated screen, having the same predetermined usage features as those of said nominal screen and a lenticular array with a pitch P computed by the formula $P = P' \cdot (1 - C / (S \cdot M))$, where S is the number of different viewpoints addressed by each pixel of said matrix;
 - replacing said nominal screen with said dedicated screen.