

The present invention relates to a system for reproducing the visual environment of a pilot in a simulator.

5 The visual environment of a pilot comprises the following main images:

- Animated images of the external scene, normally observed in flight by the pilot through the canopy of his cockpit, comprising the sky, the ground and moving objects such as aeroplanes, airborne and ground targets,
10 missiles, effects due to firings, etc.

- Animated images from the fixed sight and from the movable sight (helmut sight).

- Animated images of various instruments situated mainly on the instrument panel within the cabin.

15 The known simulators making it possible to reproduce such a visual environment are of two types: the "spherical simulators" and the "trainer".

The "spherical simulator" comprises a sphere of 8 to 12 metres in diameter (Figure 2), the internal
20 surface of which constitutes a concave, wide-angle reflector screen 20. A reproduction of the aeroplane or helicopter cockpit 21, in which the pilot is placed, is situated at the centre of the sphere.

The view of the ground as well as that of the sky
25 are simulated, for example, by two images projected onto the sphere and produced by a projection device 22, placed above the cockpit, which comprises two objectives of the "fish-eye" type, oriented in opposition and situated on either side of the centre of the sphere.

30 The roll and yaw effects are obtained by the rotation of the two fish-eyes about the centre of the sphere.

The images of moving objects are obtained by means of projection systems 23 placed above and behind
35 the cockpit.

The image from the fixed sight is presented by an optical device 24 installed in the cockpit.

One variant (Figure 3) of this spherical simulator employs two fixed fish-eye objectives 30 and 31

arranged on either side of the cockpit out of the view of the pilot. These two fish-eyes project on the screen two juxtaposed images 32 and 33 originating from two light-valve type TV projectors connected to a synthetic image computer 34 generating the sky and the ground, situated in front of and behind the cockpit, taking account of the effects due to the changes in attitude and in position of the simulated aircraft.

The spherical simulator and its previously described variant present all of the images of the external scene, from the fixed sight, from the instrument panel, etc., while respecting, as in reality, the apparent magnitude and the relative position of each of the elements of these images with respect to the cabin and to the usual references of the pilot, and while respecting the field of view illustrated by Figure 1.

Such a type of simulator functions very well, but is very expensive.

The second device of the "trainer" type (Figure 4), in order to reproduce the environment of the pilot, uses sub-assemblies such as television monitor 40 or commercially available projector, specifically presenting the images of the external scene 41 on a flat screen without, contrary to the spherical simulator, respecting the apparent magnitude and the relative position of each of the elements of the external scene with respect to the cockpit and to the references of the pilot.

Thus, the image of the frontal external scene, which in reality covers a solid angle of 2π steradians, is presented by means of the flat screen over a solid angle 41 less than 0.5 steradian, depriving the pilot, especially in his peripheral field of view, of the references necessary for the conduct of a mission.

This second type of simulator is inexpensive, but is not satisfactory from the point of view of the realism of the reproduction of the visual environment.

From the document FR-A-2 438 308, there is known a visual display device in which the images originating from several projectors pass through one or two very-

wide-angle "fish-eye" objectives, which does not make it possible to obtain better brightness and definition, for the information originating from some of the projectors, than for that originating from the other projectors.

5 From the document GB-A-2 091 193, there is known a visual display device in which all the projectors are outside the projection sphere, which requires the use of several projectors in order to obtain a panoramic image with a very wide field.

10 The subject of the present invention is a system for reproducing the visual environment of a pilot in a simulator, a system which is inexpensive, easily reconfigurable and reproduces the most realistic visual environment possible, while observing the following
15 constraints:

- respect for the apparent magnitude and for the relative position of each of the elements of these images with respect to the cockpit and to the usual references of the pilot, such as the longitudinal fuselage datum
20 (LFD) axis and the reference axis of the sight image, etc.,

- respect for the dimensions of the field of view which the pilot can explore by turning his head as in reality. The limits of this field of view are illustrated
25 by Figure 1, which is an example defining the boundary between the region 10 observed through the cockpit and the region 11, obscured by the cockpit comprising the instrument panel.

The visual environment reproduction system in
30 accordance with the invention includes an at least approximately spherical wall having dimensions of the same order of magnitude as those of a real aircraft cockpit, produced in an at least partially translucent material, at least one part of at least its inner face
35 being treated so as to form an image projection screen, this wall being associated with at least one internal image projector and with at least one external image projector, the internal image projector being tasked with projecting images with a wide optical field, and the

external projector being tasked with projecting high-definition images. For preference, the spherical surface has a diameter lying between about 1 and 3 metres. Its thickness is about 2 to 10 mm.

5 The present invention will be better understood on reading the detailed description of several embodiments, taken as non-limiting examples and illustrated by the attached drawing, in which:

10 - Figure 1, already mentioned, is a diagrammatic representation of the field of view of a pilot,

 - Figures 2 to 4, also already mentioned, are diagrammatic views of simulators of the prior art,

 - Figure 5 is a diagrammatic view of a system in accordance with the invention,

15 - Figures 6 to 8 are diagrammatic views of three embodiments of the instrument panel of the system of Figure 5, and

 Figures 9 to 12 are block diagrams of various embodiments of the internal projection device of the system of Figure 5.

20 An image projection sphere has been described below, but it is clearly understood that it is possible to have a hemisphere or even a substantially spherical wall, for example a wall formed by a large number of
25 small juxtaposed plane facets.

 The system of the invention essentially includes a small-diameter sphere-screen 51: about 1 to 3 metres. This sphere 51 is associated with a simulated aircraft cockpit 52 (helicopter or aeroplane) and with internal 53
30 and external 54 projection devices. This system makes it possible to visually display the frontal scene on a field greater than or equal to 2π steradians, such as that represented in Figure 1.

 According to one advantageous embodiment, the
35 sphere-screen 51 is produced from two transparent front and rear hemispheres 55, 56 manufactured separately by hot blow moulding from two plane sheets of plastic of the "Altuglas" type and then assembled by cold bonding to form a complete sphere in which an aperture 57 is formed

allowing the installation of the pilot.

5 The sphere 51, or at least the front hemisphere 55, is treated on its internal and external faces in such a way as to make it possible to project the images of the visual environment thereon from projection devices 53 and 54. The screen thus obtained functions simultaneously in direct projection for the projectors 53 and in back-projection for the projectors 54.

10 The set of images originating from the projectors 53 and 54 are [sic] viewed on one of the faces of the sphere 51, advantageously on the inner face. Thus, in certain regions of this inner face, for example in the "sight" region 58, it is possible to superimpose four different images: the images of the sight produced by an external projector 59, the images of the landscape
15 originating from external projectors 501 (which are three in number, for example, as represented in Figure 5), the images of the sky originating from an internal projector 502, and the images of targets originating from an
20 internal projector 503.

The optical characteristics of at least a part of the sphere-screen can be modified, either by varying the characteristics of the layers of coating deposited on at least one of the two, internal and external, faces of the
25 sphere, or by frosting one of these two faces. The layers of coating can be layers of paint, and it is possible to vary their thickness and/or their colour. In the simplest case, white paint is used. It is possible also to use layers of paint and the frosting. In this case, the
30 layers of paint can be deposited on one face, and the frosting produced on the other face, or layers of paint can also be deposited on the frosting.

This treatment by layers of paint and/or frosting of the surfaces of the sphere makes it possible to adapt
35 the system to the luminous power of the projectors used. A coating of very thick paint deposited on the inner surface of the sphere makes it possible to obtain an albedo (screen optical efficiency) which is high for the images projected from the inside of the sphere, and a

lower albedo for the images which are projected from the outside of the sphere.

According to one advantageous characteristic of the invention, for producing the sphere-screen, a plastic is used which is slightly coloured throughout its bulk, in such a way as, when working in back projection, to attenuate the multiple reflections occurring, within the plastic of the screen, on the plastic/air interface. These reflections cause a halo to appear around points of the image produced on the internal face of the sphere. The use of a coloured plastic makes it possible to increase the contrast of the images produced by back projection, especially images of the fixed sight.

According to one embodiment of the invention, one or more regions of the spherical screen, for example the region for projection of the image of the fixed sight, are replaced by flat screens, in such a way as to simplify the external optical projection devices 54, which can then be everyday commercially available projectors. These flat screens can be produced with the same material as that of the sphere or with a different material. They can be fixed, for example by bonding, onto the sphere, or can also be fixed between the sphere and the pilot.

The piloting cockpit 52, or more exactly the seat 504 for the pilot, is arranged in the sphere 51 in such a way that the eye of the pilot is close to the centre of the sphere-screen, at a distance from this centre less than about 40 cm.

So as to facilitate the introduction of the pilot into the sphere, the system is equipped with a seat 504 which is movable on rails 505 penetrating from the outside of the sphere towards its interior. The pilot sits on the seat 504 outside the sphere and, as soon as he is seated and, if necessary, strapped in, a motor (not represented) moves the seat 504 on the rails 505 along to the correct position (that is to say, as specified above, the position for which the eye of the pilot is as close as possible to the centre of the sphere), for which the seat 504 is locked in movement. Needless to say, the seat

504 includes means (not represented) for adjustment in height and in inclination.

As represented in Figure 6, the instrument panel 61 of the system of the invention can include real instruments 62. The instrument panel 61 is surmounted by the sight image 63 which, as detailed above, may be formed either on the sphere itself, or on a flat screen fixed to the sphere, or finally on a flat screen fixed in a position closer to the eye of the pilot than the sphere is. The sight image is obtained by virtue of an external projector referenced respectively 506, 64, 71, 81 in Figures 5, 6, 7 and 8.

As represented in Figure 7, the animated image 72 of all the instruments of the instrument panel can be projected onto the sphere or onto a flat screen (fixed on the sphere or in front of the latter) by virtue of an external projector 73 (referenced 507 in Figure 5).

Finally, as represented in Figure 8, the system may include an instrument panel 82 in which a cutout 83 is formed, allowing the pilot to see the projection, carried out by an external projector 84 arranged under the projector 81 of a "head midway" image 85. The instrument panel 82 is equipped with real instruments 86, and with a control unit 87.

The set of internal projectors 502, making it possible to project the image of the ground and of the sky onto the sphere-screen, includes, according to a preferred embodiment of the invention, a high-brightness tube projector and a laser-source projector associated with the same projection fish-eye objective. Their embodiment details have been represented in Figure 9.

The high-brightness cathode-ray tube projector 900 forms, on the front face of its tube, an image 901 of the sky (light region) and of the ground (dark region) traced in television mode, according to a standard which may be any one of the existing standards (for example with 625, 875 or 1024 lines).

An optical device with lenses 902 forms the image of the front face of the cathode-ray tube in the focal

plane 903 of a fish-eye objective 904 which projects this image onto the internal face of the spherical screen 905 (sphere 51 of Figure 5), in such a way as to cover at least half of this screen, i.e. 2π steradians.

5 The laser projector comprises a laser generator 906 which emits a visible beam 907 modulated in intensity by a transducer, for example a piezoelectric transducer, and with an optical crystal, modulator referenced 908.

10 A deflector device 909 using two galvanometric mirrors deflects the laser beam in calligraphic mode over a field extending, for example, over $\pm 4.5^\circ$ in elevation and $\pm 4.5^\circ$ in azimuth.

15 The laser beam thus deflected is reflected by a semi-reflecting plate 910, arranged between the optical device 902 and the objective 904, towards this objective 904. The objective 904, with respect to this laser beam, plays the role of scanning amplifier and converts the deflection of $\pm 4.5^\circ$ into a deflection ranging from $\pm 90^\circ$ to $\pm 110^\circ$ according to the type of fish-eye used.

20 On the spherical screen 905, the laser beam forms an image (911) consisting of several vectors representing the horizon line and a grid pattern on the ground.

25 An electronic interface 912 makes it possible to derive the X, Y and video analog signals for control of the devices 909 and 908 respectively, in real time.

30 The abovementioned images 901 and 911, superimposed on the screen 905, are produced by a digital computer 913 which generates these two images, taking account of the optical law of the fish-eye 904 with respect to the spherical screen, so as to produce, on this screen, images which are as little distorted as possible with respect to what the pilot should observe. The superimposition of these two images, for certain applications, makes it possible to present a brighter horizon line, which is more contrasted and positioned with accuracy, although the horizon line produced by the tube 900 alone is less bright and less contrasted because of the size of the screen surface to be illuminated and of the integrating spherical screen phenomenon which

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destroys the general contrast of the image.

According to a simplified variant, not represented, the high-brightness tube projector 900 is used alone, with its optical devices 902 and 904 and the
5 computer 913.

According to another variant, represented in Figure 10, the high-brightness tube is replaced by a laser generator projector operating in television scanning so as to trace out an image consisting, for example,
10 of two interlaced frames each of 128 lines, in order to represent the sky (light region) and the ground (dark region). This system, in addition to the devices 904, 905, 906, 908, 909, 910 and 912, identical to those of Figure 9, includes the assembly 1000 consisting of the
15 devices 906A, 908A, 909A and 912A which are identical to the devices 906, 908, 909 and 912 respectively. The computer 913A is similar to the computer 913, but is provided also to control the assembly 1000.

The divergence of the laser beam projected by the
20 assembly 1000 towards the fish-eye objective 904 via the semi-transparent mirror 910 is adjusted so that the diameter of the laser spot projected onto the screen 905 covers two to three scanning lines in such a way as not to cause the television frame to appear on the screen.

In Figure 11 has been represented a simplified
25 diagram of a device installed in the sphere-screen close to the projectors, for projecting simplified images of targets represented by several independent moving spots, of diameters which are variable as a function of the
30 distance from each target to the pilot.

This device, for each target image projected, includes a light source 1110, an attenuator disc 1111 controlled in rotation by a stepper motor 1112 so as to control the brightness of the projected spot, a variable
35 diaphragm 1113 controlled by a stepper motor 1114 controlling the diameter of the projected spot, a shutter 1115 controlled in rotation by a stepper motor 1116 so as to obscure the spot permanently or according to a variable frequency or intermittently (blinking), a projection

device 1117 forming the image of the diaphragm 1113 on the spherical screen 51, a mirror 1118 which is movable in rotation about two rectangular axes X1, X2 and controlled by the stepper motors 1119 and 1120 respectively for each of these axes, so as to move the spot on the spherical screen 51, and a stepper motor 1123 associated with a disc 1122 comprising several windows equipped with coloured filters so as to choose the colour of the projected spot. All the stepper motors are controlled by an electronic computer 1121 providing the links with the main electronic computer (not represented) of the system, the initialization of the stepper motors in zero position, on switching on the system, and the derivation of the micro-step for control of the motors 1119, 1120 for positioning the mirror 1118 with a resolution close to one minute of arc.

According to one variant of the device of Figure 11, represented in Figure 12, the spot is replaced by a monochrome or black-and-white image, for example of 256 lines, obtained by scanning and modulation of one or two laser beams.

In this device of Figure 12, the elements 1111, 1112 and 1118 to 1121 are identical respectively to those of the same reference of Figure 11. The other elements of Figure 11 are replaced by an assembly 1210 including the elements 906, 908, 909 and 912 which are respectively identical to the elements of the same reference of Figure 9. The interface 912 is controlled by a computer 1220 similar to the computer 913 of Figure 9, and this computer 1220 is linked to the central computer of the system. The computer 1220 produces a television image, taking account of the effects of rotation of the images induced by the movable mirror 1118, of the attitude of the target in flight, of its distance and of its position with respect to the observer.



CLAIMS

1. System for reproducing the visual environment of a simulator pilot, characterized in that it includes an at least approximately spherical wall (51) having dimensions of the same order of magnitude as those of a real aircraft cockpit, produced in an at least partially translucent material, at least one part of at least one of its faces being treated so as to form an image projection screen, this wall being associated with at least one internal image projector (53) and with at least one external image projector (54), the internal image projector being tasked with projecting images with a wide optical field, and the external projector being tasked with projecting high-definition images.
2. System according to Claim 1, characterized in that the spherical wall has a diameter lying between about 1 and 3 metres.
3. System according to Claim 1 or 2, characterized in that the thickness of the wall is about 2 to 10 mm.
4. System according to one of the preceding claims, using a substantially spherical wall, characterized in that this wall is produced from two hemispheres (55, 56) manufactured separately by hot blow moulding from two plane sheets of plastic, and then assembled to form a sphere in which an aperture (57) is formed allowing the installation of the pilot.
5. System according to one of the preceding claims, characterized in that the treatment of at least one part of at least the inner face of the wall consists in depositing layers of coating.
6. System according to Claim 5, characterized in that the layers of coating are layers of paint.
7. System according to Claim 6, characterized in that the paint is white paint.
8. System according to one of Claims 5 to 7, characterized in that the thickness of the coating is varied.
9. System according to one of the preceding claims, characterized in that the treatment of at least one part of at least one face of the wall is a treatment allowing



frosting to be obtained.

10. System according to any one of the preceding claims, characterized in that the wall is made of plastic coloured throughout its bulk.

5 11. System according to any one of the preceding claims, characterized in that at least one region of the wall is formed by a flat screen (58).

12. System according to Claim 11, characterized in that the flat screen is fixed onto the wall.

10 13. System according to Claim 11, characterized in that the flat screen is fixed between the wall and the pilot.

14. System according to any one of the preceding claims, with a piloting cockpit (52) arranged within the wall and including a seat (504) for the pilot, characterized in that the seat is arranged in such a way that the eye of the pilot is close to the centre of the sphere formed by the wall, at a distance from this centre less than about 40 cm.

15 20 15. System according to Claim 14, characterized in that the seat (504) is movable on rails (505) and adjustable in height and in inclination.

16. System according to any one of the preceding claims, including an instrument panel (61), characterized in that this instrument panel includes real instruments (62, 85).

17. System according to Claim 16, characterized in that at least a part of the instrument panel forms a screen for at least one external projector (73, 84).

30 18. System according to any one of the preceding claims, characterized in that the internal image projector device, projecting the animated image of the sky and of the ground, includes a high-brightness cathode-ray tube projector (900) associated with a "fish-eye" objective (904).

35 19. System according to any one of Claims 1 to 17, characterized in that the internal image projector device, projecting the animated image of the sky and of the ground, includes a laser generator projector (1000)



operating in television scanning mode, associated with a "fish-eye" objective (904).

20. System according to Claim 18 or 19, characterized in that the internal image projector device further includes a second laser generator projector (906), modulator and deflection device (909).

21. System according to Claim 20, characterized in that the laser generator projector produces a trace in calligraphic scanning.

22. System according to Claim 20 or 21, characterized in that the laser generator projector traces a horizon line and a movable grid pattern of the ground on the projection wall.

23. System according to any one of the preceding claims, characterized in that the images of the targets are produced by movable spots (Figure 11) of variable diameters, capable of being at least partially obscured.

24. System according to Claim 23, characterized in that the spots may be obscured according to a variable frequency.

25. System according to any one of Claims 1 to 22, characterized in that the images of the targets are produced by a laser generator projector (1210).