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DESCRIPTION

SIMULATION ARRANGEMENT

5 The present invention relates to a simulation arrangement and more particularly to a fixed-bed vehicle simulation arrangement in which the operator is not physically moved around by the arrangement.

10 Fixed bed simulators for training and entertainment purposes such as flight simulators and video games for driving are available at a variety of levels of sophistication. The crudest simulators provide the operator with a view from the vehicle which is merely translated in space relative to the previous view. More sophisticated simulators such as that described in Van Winsum, W., "GIDS Small World Simulation" Chapter 9 in Michon, J.A., "Generic Intelligent Driver Support", Taylor and Francis, London also rotate the view to provide the operator with an objective view from the simulated vehicle. Such simulators provide a much more realistic output to the operator than the crudest types of simulator. However, they are not as realistic (or as expensive) as a full simulator which moves the operator around.

15 One difficulty that has arisen in the development of a fixed-bed simulator which both rotates and translates the view provided to the operator is that the operator sees a situation that does not correspond to what he feels. This anomaly can cause feelings of nausea in the operator.

20 It is an object of the present invention to provide a fixed-bed simulation arrangement which results in reduced feelings of nausea in the operator.

25 According to the present invention there is provided a vehicle simulation arrangement comprising display means for displaying a view from a simulated vehicle to an operator, at least one control device for actuation by an operator, means responsive to the at least one control device for maintaining an objective direction of the simulated vehicle, characterised in that lag means are provided for delaying the objective direction of the simulated vehicle before it is applied to the means for displaying a view from

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the simulated vehicle.

5 The provision of a delay between the objective direction of the simulated vehicle and the direction of view actually provided to the operator means that the simulation apparatus does not always show the operator a view looking along the vehicle axis as is done in known systems and this is found to be less nausea-inducing. A simulation apparatus in accordance with the invention has also been found to be easier to control.

10 In order to generate the view to be shown to the operator, two pieces of information are required. These are firstly the calculated position of the vehicle within the simulator's model of the world, and secondly the direction in which the vehicle is pointing. The crude simulators discussed above ignore the direction information completely while the more sophisticated simulators rotate the view to take account of vehicle direction. In the real world, however, or on a moving bed simulator, the driver senses when he is turning and unconsciously turns his eyes to tend to stabilise his direction of view, even when his body is turned. The problem with sophisticated fixed-bed simulators is that part of the sensation of motion is lost and the unconscious stabilisation process cannot work so the field of view appears to change more than it would if the cues which help stabilisation were present.

20 In the present invention, the perceived change of direction lags relative to the objective direction, and the time constant of the lag is a measure of how quickly the change of direction is perceived. The perceived change of direction is due, in the real world, to imperfection in the eye's stabilisation. The eye's stabilisation system may be assumed to act as a simple lag, with a time constant of 100ms. The turning of the eye therefore lags the objective change in direction by this amount. The perceived change of direction is the difference between the turning of the eye and the objective change of direction. Values used in the simulator may be between, for example 0.05 and 0.25 seconds. The lag means may include differentiation means for providing a view to the display means which is rotated by an amount proportional to the rate of change of objective direction of the simulated vehicle

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For sharp turns of the simulated vehicle, the difference between the objective view and the view provided to the operator may be too great for the simulation to be realistic. To overcome this difficulty a non-linear transfer function may be used whereby for small changes in direction the view direction lags the objective change of direction, but for large changes the full change is passed to the display generator.

Alternatively, where a simulated car is driven on a track, for example, the simulation apparatus may include means to provide a particular course around sharp corners and only the objective vehicle's deviations from this course are applied to the differentiator means and thence to the operator.

The location model of the simulator may conveniently be stored as a series of small blocks. These may be arranged as a standard library of blocks and a sequence listing the order in which the blocks are to be called up

The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a block schematic diagram of a simulation apparatus in accordance with the present invention,

Figure 2 shows a flow chart for the operation of a simulation apparatus,

Figure 3 shows a diagrammatic view of the storage of a road in the simulation apparatus, and

Figure 4 shows the view of Figure 3 transformed into a perspective view from the simulated vehicle.

Referring to Figure 1, the simulation apparatus, for example a car simulator, has one or more controls for actuation by the operator, in this case a steering wheel 10. The steering wheel is arranged to rotate a potentiometer which is connected to an analogue to digital converter (A/D) 12. Other techniques for measuring the position of the steering wheel such as optical or magnetic shaft encoders could be used instead. The A/D 12 provides a digital output which is connected to a model 14 of the vehicle.

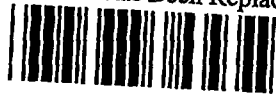


5 The model of vehicle behaviour is arranged in conventional manner to provide position and direction information according to the characteristics of the simulated vehicle and the operator's use of the controls. Instead of applying an output of the model 14 to a display or display generator, that output is connected to a lag means 16. The lag means 16 includes a differentiator for providing a view to the display means which is rotated by an amount proportional to the rate of change of objective direction of the simulated vehicle. The rate of change of vehicle direction provided at the output of the model 14 determines the amount of change of direction to the
10 subjective vehicle position. If a large rate of change of direction is applied to the means 16 by virtue of the operator turning the steering wheel 10 sharply, a greater direction change is applied to the display. Thus, the display of a sharp turn to the operator will show as a greater change of direction than a more gentle turn and vice versa. A differentiator having a
15 time constant of 100ms has been found to give good results.

The output of the means 16 is connected to a display generator 18 which derives the operator's view from the vehicle from the position information in a conventional manner and provides the view to the display
20 22. Because of the inclusion of the means 16, the view provided to the operator on the display 22 will differ from the objective axis of the vehicle during and after turning. For simplicity only a steering wheel 10 has been shown and described but it will be understood that the simulation may also comprise a throttle and brake in the manner of known car simulators or more sophisticated controls in the case of a flight simulator and so on.

25 The display generator 18 is optionally connected to a location model 20 which provides details of a racetrack or other simulated environment in which the vehicle is being operated. The location model 20 may also be connected to the lag means 16 to provide a predetermined course around sharp corners. This predetermined course is subtracted from the objective
30 course and the difference processed by the lag means.

The models 14, 20, the lag means 16 and the display generator 18 may conveniently be implemented by a programmed microprocessor



arranged to execute the program steps illustrated in Figure 2.

The flow chart steps have the following functions:

30 - start

32 - set elapsed time to zero

34 - read input from operator's controls

36 - apply time elapsed and current position to vehicle model

38 - derive rate of change of direction term proportional to rate
of objective vehicle turning

40 - derive subjective direction of view from vehicle from rate
of change of direction term and eye stabilisation lag

42 - display subjective view from vehicle

44 - increment elapsed time

This second embodiment of the invention operates in a similar manner to the first embodiment to provide the operator with a view from the vehicle whose direction lags by an amount according to the rate of change of objective vehicle turning.

The location model, or image which the operator of the simulation apparatus sees, may be provided in the following manner which is particularly suitable for implementing on a microprocessor which has limited processing speed or limited memory, such as a personal computer.

Figure 3 shows a plan view of a portion of a road 50 upon which the simulated vehicle is to be driven and this road is shown divided into 10 blocks 52, 54, 56, 58 and 60. The same numbered blocks represent the same road pattern. The road 50 may be stored as a number of individual blocks or as a library of standard blocks and a sequence of reference numbers which specify the order in which blocks are selected from the library of standard blocks. The former option allows greater freedom of design and may be marginally faster but the latter will generally save a large amount of storage space with a minimal sacrifice of flexibility. In use the standard blocks may be retrieved simply by specifying their reference number. Thus a large road layout or racetrack may be stored as a number of



short identity codes. The road layout within the blocks may be stored as a number of pixel values for the left and right of the road or as a value for one side of the road and a width measurement. To ensure that the road matches up with that of an adjacent block, an offset value may be included in each block which is applied to displace the following block relative to it. While ten blocks are shown in the figure, in practice a larger number of the order of 50 or more will be used to provide a reasonable level of realism. Each block will then represent of the order of a metre of actual road. For increased realism blocks relating to approximately 10 cm of actual road may be used.

To provide a perspective view of the road to an operator of the simulation apparatus, the following transformation is performed. The identity numbers of the relevant blocks for the present position of the vehicle are read out and their respective layout data is retrieved. The closest block will be displayed in the greatest detail and the furthest block will displayed in the least detail, typically as a single line of pixels on the screen only. The relation between the plan of each block and the image on the screen thus depends upon the distance of the block from the simulated vehicle. There now exists the possibility of a tradeoff between processing power and amount of memory available to the processor. If processing power is limited but memory is relatively plentiful the image of the road ahead for each block may instead be stored as a number of perspective views dependent upon the distance from the simulated vehicle. The relevant view for that portion of the road is then simply recalled on the basis of distance from the simulated vehicle. If memory is more limited, however, the perspective views can be derived from the plan views using simple interpolation techniques and narrowing of the road as it approaches the vanishing point in the distance. In either case the result should be as shown in figure 4 where the perspective view 50' of the road is displayed on a screen 70 and vanishes at the horizon 72. The blocks are labelled with dashed numbers which correspond to those in Figure 3. The four blocks of road labelled 52' nearest the operator thus become progressively shorter and narrower as their distance from the simulated vehicle increases. The blocks of the perspective



5 road 50' that are still further away are shorter and narrower. To derive the perspective version of a block from the plan view version it is sufficient to shorten and narrow the block dependent upon the distance from the simulated vehicle but for improved realism when sufficient processing power is available, more sophisticated transforms may be used as are known in the simulator art, for example from 'Computer Graphics Principles and Practice' by Foley, van Dam, Feiner and Hughes and published by Addison-Wesley. Where the simulator provides a predetermined course along the road from which the perceived direction of view is derived, this may conveniently be stored in the location model blocks.

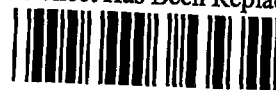
10 Next the heading of the simulated vehicle on the road is derived from the vehicle model, for example from the past heading of the vehicle, the position of the operator's steering wheel and any other factors such as wheel slip which depend upon the sophistication of the simulator. The direction in which the road ahead is pointing (in other words since the operator is inside the simulated vehicle, it is the road that is seen to move when the vehicle turns) is then derived and displayed. To conserve computing power it is possible to adjust the direction of the road on the screen using a shear transform provided in the display hardware where such a transform is available. Similarly, the horizontal location of the road relative to the vehicle may be adjusted by a linear transformation or left-right hardware scroll. The simulation then repeats these steps to derive the next view to be provided to the operator.

15 While a car simulation apparatus has been described it will be understood that the invention may be applied to simulators for aeroplanes, boats, motorcycles and so on. Where a simulator in accordance with the invention is used to simulate an aeroplane or other vehicle which has freedom to move up and down as well as left to right, a lag may also be applied to changes of elevation angle as well as changes of heading.

From reading the present disclosure other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the design, manufacture and use of

vehicle simulators and component parts thereof and which may be used instead of or in addition to features already described herein. Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure of the present application also includes any novel feature or any novel combination of features disclosed herein either explicitly or implicitly or any generalisation thereof, whether or not it relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as does the present invention. The applicants hereby give notice that new claims may be formulated to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

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CLAIMS

5 1. A vehicle simulation arrangement comprising display means for displaying a view from a simulated vehicle to an operator, at least one control device for actuation by an operator, means responsive to the at least one control device for maintaining an objective direction of the simulated vehicle, characterised in that lag means are provided for delaying the objective direction of the simulated vehicle before it is applied to the means for displaying a view from the simulated vehicle.

10 2. A simulation apparatus as claimed in Claim 1, wherein the lag means has a time constant of between 0.05 and 0.5 seconds.

15 3. A simulation apparatus as claimed in Claim 1 or Claim 2, wherein the lag means includes differentiation means for providing a view to the display means which is rotated by an amount proportional to the rate of change of objective direction of the simulated vehicle.

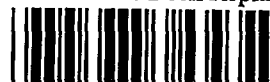
20 4. A simulation apparatus as claimed in Claim 1, Claim 2 or Claim 3, further comprising means for providing a predetermined course and means for subtracting the predetermined course from the objective course to provide a difference course to the lag means.

25 5. A simulation apparatus as claimed in any one of the Claims 1 to 4, further comprising means for storing a plurality of location model blocks arranged for display in sequence.

6. A simulation arrangement as claimed in any one of the Claims 1 to 4, further comprising means for storing a plurality of location model library blocks, means for storing at least one sequence of library blocks and means for reading library blocks in accordance with the stored sequence.



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5 7. A simulation arrangement as claimed Claim 5 or Claim 6, wherein the location model blocks comprise a plan representation of the location model, the arrangement further comprising transform means for converting the representation of the location model to a view from the simulated vehicle.

10 8. A simulation arrangement as claimed in Claim 5 or Claim 6, wherein each of the location model blocks contains at least one representation of the location model as viewed from the simulated vehicle.

9. A simulation arrangement as claimed in Claim 8, wherein each of the location model blocks contains a plurality of representations of the location model at different distances as viewed from the simulated vehicle.



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ABSTRACT

SIMULATION ARRANGEMENT

5 A vehicle simulator is provided with a control device (10) for actuation
by an operator which device's input is digitised (12) and fed to a vehicle
model (14). The model (14) maintains an objective position and direction for
the simulated vehicle which are fed to a lag means (16). The lag means
operates to delay the rate of change of objective direction of the simulated
vehicle to provide a subjective direction to a display generator (18). The
10 display generator (18) provides a subjective view based on the objective
position and subjective direction of the simulated vehicle on a display (22).

(Figure 1)

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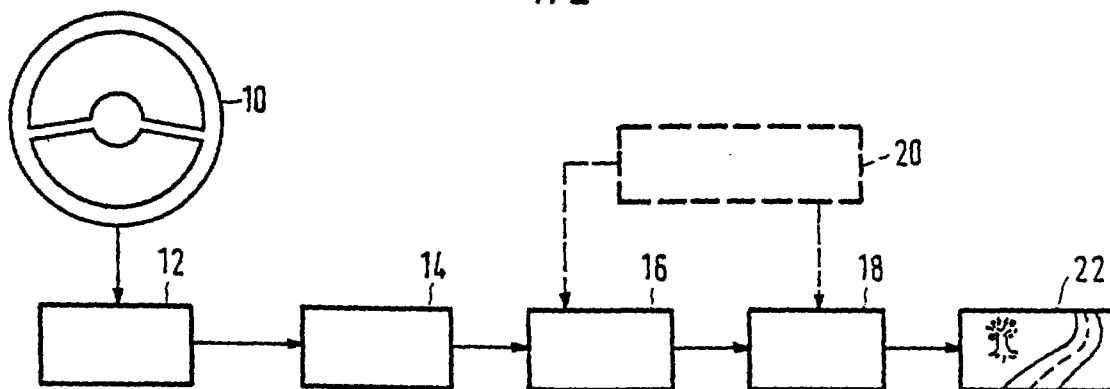
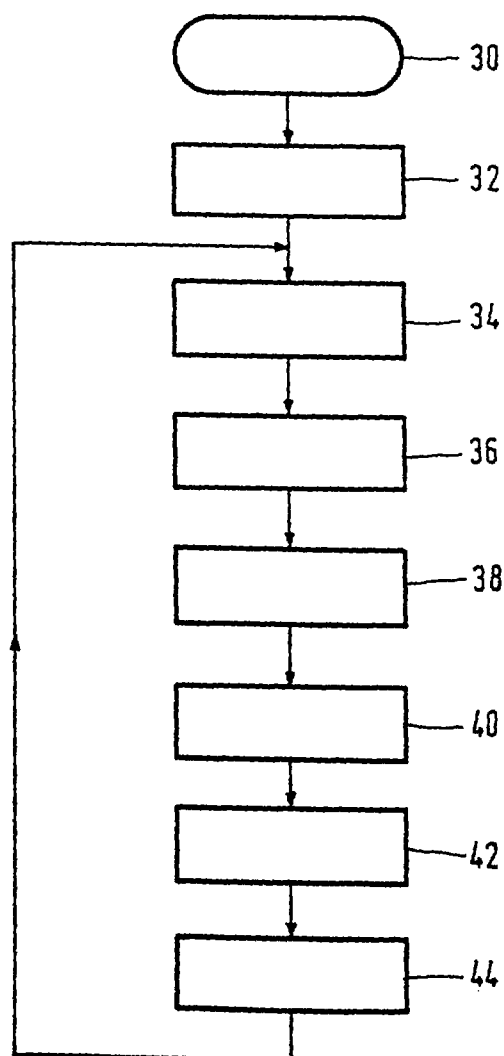


FIG.1



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FIG.2

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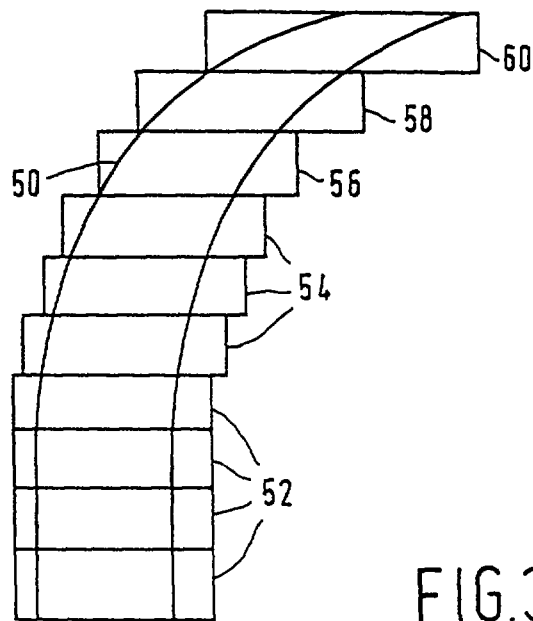


FIG. 3

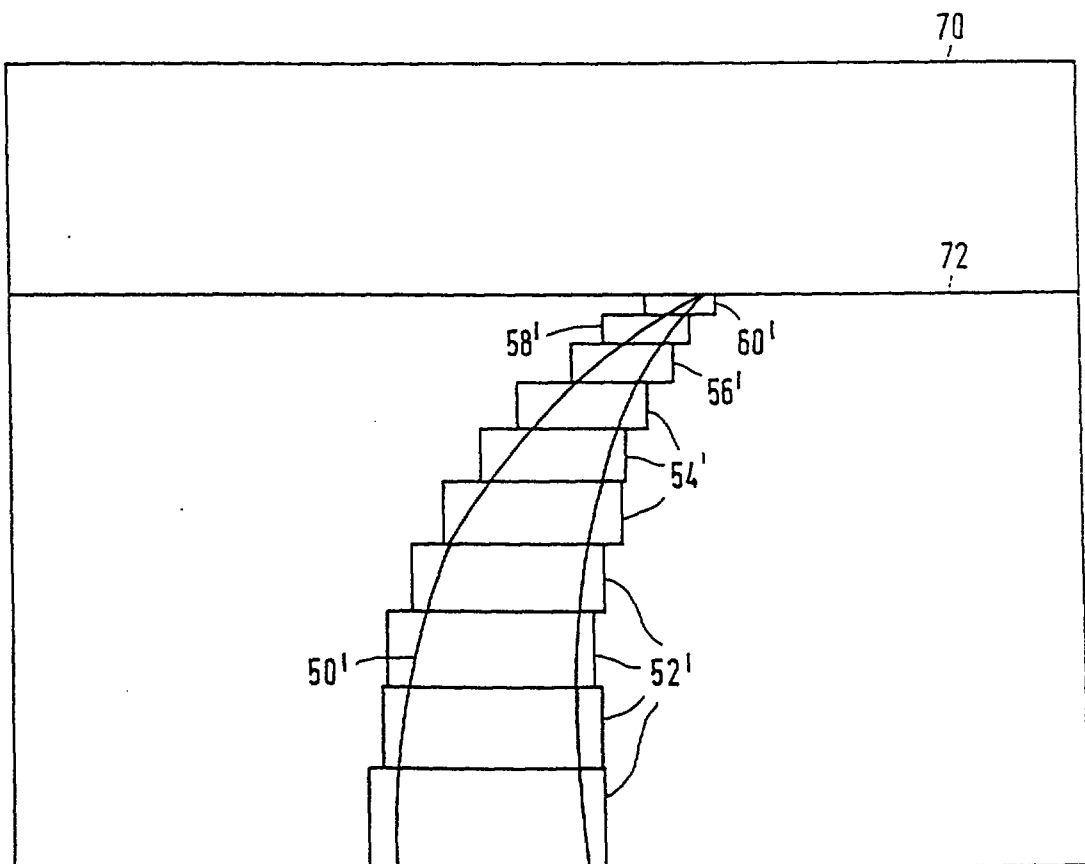


FIG. 4

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The invention relates to a scanning device for scanning a record carrier which comprises parallel, optically detectable tracks, the device comprising an optical system for focusing, *via* the record carrier, a main radiation beam, a first and a second auxiliary radiation beam on a radiation-sensitive main detector, a first and a second auxiliary detector respectively, while the main detector and auxiliary detectors comprise each at least a first and a second sub-detector, the device comprising a tracking control system for controlling, in response to a tracking error signal, a position of a read spot caused by the main radiation beam on the record carrier, which tracking control system can be brought to a first or a second operating state in which tracking control system in the first operating state first generating means for generating tracking error signals are active for generating as a tracking error signal a differential push-pull signal which represents a combination of mutual differences between detector signals from sub-detectors of individual detectors, and which tracking control system comprises second generating means for generating tracking error signals which second generating means are active in the second operating state and differ from the first generating means for generating tracking error signals.

Such a device is known from EP-A-0.525.896. Prior-art device is, in essence, intended for reading out record carriers which have a track pitch that is approximately half the track pitch customary for so-called Compact Discs. To make the reading of Compact Discs possible too, the device comprises additional provisions. When the record carrier having half the track pitch is read out, the tracking control is brought to the first operating state. In this first operating state a tracking according to the so-called three-spot-push-pull principle is realised. The auxiliary radiation beams are then focused in such a way that in the case where the main radiation beam hits the centre of a track, the auxiliary read spots caused by the auxiliary radiation beam are positioned on either side of the track followed by the main read spot and shifted by distances corresponding to half the track pitch. For each of the three read spots (main read spot and auxiliary read spots), a push-pull signal is derived from the difference between the detector signals of the associated detectors. The push-pull signals thus obtained are combined to the three-spot-push-pull signal which is thereafter used as a tracking error signal in the tracking control system, so that the position

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of the main read spot is kept centralized on the track.

When the Compact Disc is read out, the tracking control system is brought to the second operating state. In this operating state the control system keeps the centre of the main radiation beam focused on the edge of one of the tracks.

Prior-art device cannot be used for applications in which the main read spot is to be kept centralized on one of the tracks for both types of record carriers such as, for example, applications as described in EP-A-0.482.964.

It is an object of the invention to provide a device in which the main read spot can be kept centralized on one of the tracks when either type of record carrier is scanned.

According to the invention this object is achieved by a device as defined in the opening paragraph, characterized in that the second generating means for generating tracking error signals comprise deriving means for deriving as the tracking error signal a signal that represents a difference between the sums of the detector signals of the sub-detectors of the first and of the second auxiliary detector.

The device according to the invention is advantageous in that a tracking error signal can be derived for either type of record carrier on the basis of detector signals, without adaptations for focusing the radiation beams being necessary in the optical system. For that matter, if a record carrier having a specific track pitch is scanned and the distance between the auxiliary read spots and the track followed by the main read spot is equal to half the track pitch, the distance between the auxiliary read spots and the track followed by the main read spot will, in essence, be equal to a quarter of the track pitch if a record carrier having a track pitch that is twice this track pitch is scanned. For distances between the main read spot and the auxiliary read spots, which distances are equal to half the track pitch, it appears that a tracking error signal obtained according to the three-spot-push-pull principle is little sensitive to variations of parameters which may, for example, be caused by eccentricity. For distances between the main read spot in the auxiliary read spots, which distances are equal to a quarter of the track pitch, a tracking signal obtained on the basis of the difference between the radiation received by the auxiliary detectors also appears to be little sensitive to said variations of parameters. With the device according to the invention it is thus possible to realise in a highly simple manner a reliable tracking for the scanning of both a first type of record carrier and a second type of record carrier, whereas the track pitches on the two different types of record carriers have a ratio of 1:2. With said 1:2 ratio of the track pitches, the insensitivity to variations of parameters is optimized. However, there should be observed



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that also for track pitch ratios lying within the limits of 1.5 and 2.5, a sufficiently high insensitivity to variations of parameters is obtained.

The invention will be further explained with reference to the drawing Figures 1 to 5, in which:

Fig. 1 shows an embodiment for the scanning device according to the invention;

Fig. 2 shows a top view of a detector system to be used in the device shown in Fig. 1,

Figs. 3 and 4 show top views of two different types of record carriers which may be scanned by the device according to the invention; and

Fig. 5 shows an adaptation of the embodiment shown in Fig. 1.

Fig. 1 shows an embodiment for a scanning device according to the invention for scanning an optical record carrier 1, part of which is represented in a cross-sectional view. The record carrier comprises an information plane 2 in which information has stored in the form of a phase structure. This phase structure may be formed by, for example, pits or land on the information plane. The phase structure is ordered in parallel tracks 3 having a constant track pitch. In Fig. 1 the tracks are perpendicular to the plane of the drawing. The device comprises a read head 4. The read head 4 comprises a radiation source 11, for example, a diode laser, for generating a radiation beam. Furthermore, the read head 4 comprises a beam splitter, for example, in the form of a grid splitting up the radiation beam produced by the radiation source 11 into a main radiation beam 5 and two auxiliary radiation beams 6 and 7. The read head 4 comprises an optical system for focusing, via the information plane 2 of record carrier 1, the radiation beams 5, 6 and 7 at a respective radiation-sensitive main detector 8, a first auxiliary detector 9 and a second auxiliary detector 10. The optical system thereto comprises a beam splitter 13 of a customary type, for example, in the form of a semitransparent mirror for separating the beams focused at the information plane and the beams returning from the information plane. Furthermore, the optical system comprises a focusing element 14 of a customary type for focusing the radiation beams 5, 6 and 7 to small read spots 15, 16 and 17 on the information plane 2. The read spot 15 caused by the main radiation beam 5 will be designated the main read spot hereinafter. The read spots caused by the auxiliary radiation beam 6 and 7 will be designated auxiliary read spots 16 and 17 hereinafter.

Each of the main detector 8 and auxiliary detectors 9 and 10 is divided into at least a first and a second sub-detector. In Fig. 2, which shows a top view of the

detectors 8, 9 and 10, the division of the detectors 8, 9 and 10 is indicated by the lines 18, 19 and 20. Furthermore, spots caused by the radiation beams 5, 6 and 7 are referenced 21, 22 and 23 in Fig. 2. The optical system and detectors 8, 9 and 10 are dimensioned such that in the case where the main radiation beam 5 is focused on the centre line of the tracks 3 and the auxiliary radiation beams 6 and 7 are focused on the centre line between two parallel tracks 3, the spots 21, 22 and 23 are positioned centralized on the detectors 8, 9 and 10. If the read head 4 is moved in a direction perpendicular to the tracks, the spots on the detectors 8, 9 and 10 will move in a direction perpendicular to the lines 18, 19 and 20.

The device comprises a generating circuit 24 for generating tracking error signals, which circuit derives a tracking error signal SRE from detector signals S8a, S8b, S9a, S9b, S10a and S10b which are supplied by the sub-detectors of the detectors 8, 9 and 10. The tracking error signal SRE denotes the deviation between the centre line of the main read spot 15 and the centre of the track on which the main radiation beam 5 is focused. The main read spot is kept on the centre line of one of the tracks 3 by a tracking control system. In addition to the generator circuit 24 for generating the tracking error signals, the tracking control system comprises a control circuit 25 and an actuator 26. The actuator is of a customary type for effecting a shift of the read spots 15, 16 and 17 in a direction perpendicular to the tracks 3. The actuator 26 may be formed, for example, by a shift actuator for shifting the read head 4. However, other types of actuators are also suitable. The actuator 26 is controlled by the control circuit 25 which derives a control signal for the actuator 26 from the tracking error signal SRE, so that the tracking error signal is kept at a predetermined value that corresponds to a tracking error that is substantially equal to zero. The tracking control system can be brought to a first or second operating state. In the various operating states various tracking error signals are derived from the detector signals 8a, 8b, 9a, 9b, 10a and 10b. A first one of the two different operating states is intended to be used in the case where the track pitch of the tracks 3 (distances between the centres of adjacent tracks) is selected to be so large as to have the auxiliary read spots 16 and 17 positioned, in essence, in the middle between two tracks. Worded differently, the auxiliary read spots are shifted relative to the main read spot 15 in a direction perpendicular to the tracks over a distance equal to $(n+0.5)$ times the track pitch. For the purpose of illustration, Fig. 3 shows a top view of the pattern of tracks represented for the case where the auxiliary read spots 16 and 17 are shifted in a direction perpendicular to the tracks over a distance equal to half the track pitch. The tracks 3 are formed by pits which are further designated by reference numeral 60. In the device according to the invention a so-called differential push-pull



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tracking error signal Srepp is used as a tracking error signal in the case where the auxiliary read spots 16 and 17 are shifted over a distance $(n+0.5)$ times the track pitch. This signal may be derived according to the following relation:

$$Srepp = (S8a-S8b) - \Gamma/2 (S9a-S9b) - \Gamma/2 (S10a-S10b).$$

For a further explanation of the relation between the Srepp signal and the detector signals, reference be made to EP-A-0.201.603.

The signal Srepp can be derived by numerous different embodiments of circuits, for example, by a program-controlled circuit which is loaded with a suitable program for deriving the signal Srepp according to said relation.

The signal Srepp may also be derived by a so-called hard wired circuit, a possible embodiment of which being formed by the generating circuit 24 for generating tracking error signals shown in Fig. 1. This embodiment comprises a subtracter circuit 40 for determining the difference between the detector signals S10a and S10b, a subtracter circuit 41 for determining the difference between the detector signals S8a and S8b and a subtracter circuit 42 for determining the difference between the detector signals S9a and S9b. An output signal of the subtracter circuit, which signal represents the difference found, is applied to a non-inverting input of an arithmetic circuit 44 via an amplifier circuit 43 having a gain factor $2/\Gamma$. Output signals of the subtracter circuits 40 and 42 representing the differences determined by these circuits 40 and 42 are applied to inverting inputs of the arithmetic circuit 44. The arithmetic circuit 44 derives the differential push-pull tracking error signal Srepp from the received signals.

In the device according to the invention, a different tracking error signal is used for tracking if the track pitch is twice the track pitch shown in Fig. 3. Fig. 4 shows by way of illustration a top view of a record carrier having tracks with a track pitch twice that of the record carrier shown in Fig. 3.

For such a track pitch the auxiliary read spots 16 and 17 in a direction perpendicular to the tracks 3 are shifted relative to the main read spot 15 over a distance equal to a quarter of the track pitch. With such a relation between track pitch and distance between the read spots, a signal Sreca derived from the following relation

$$Sreca = (S10a + S10b) - (S9a + S9b).$$

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is used as the tracking error signal.

For a further explanation of the relation between the signal Sreca and the detector signals, reference be made to GB-1.434.834.

The signal Sreca can be derived by numerous different embodiments of circuits, for example, by a program-controlled circuit loaded with a suitable program for deriving the signal Srepp according to said relation.

The signal Sreca can also be derived by a so-called hard wired circuit of which a possible embodiment is included in the generating circuit 24 for generating tracking error signals shown in Fig. 1. This embodiment comprises an adder circuit 45 for determining the sum of the detector signals S10a and S10b and an adder circuit 46 for determining the sum of the detector signals S9a and S9b. An output signal of the adder circuit 45 representing the sum determined by the adder circuit 45 and an output signal of the adder circuit 46 representing the sum determined by the adder circuit 46 are applied to a subtracter circuit which derives the signal Sreca from these supplied signals.

By means of a selection unit 48, for example, formed by a switch and controlled by a signal Ss, either the signal Srepp or the signal Sreca can be applied to the control circuit 25 as the tracking error signal SRE. The operation of the selection unit 48 may be carried out manually by the user. However, the operation of the selection 48 is preferred to be carried out automatically. This may be effected on the basis of information obtained from the record carrier present in the scanning device. For this purpose the scanning device may comprise a detection unit which establishes the type of record carrier present in the scanning device and which applies an appropriate control signal Ss for the selection unit to the selection unit 48 in the scanning device.

The signal Ss can be obtained in numerous ways. A detection unit may comprise means which effect a shift of the read head over a defined distance and establish the number of passed tracks on the basis of one or more detector signals. This number found is a measure for the track pitch, so that the control signal Ss can be derived from this measure. Another attractive way is including codes in the information signal recorded on the record carrier, which codes indicate the type of record carrier. By detecting these codes the type of record carrier can be established and an appropriate control signal Ss can be generated. It may then be advantageous during the reading of the information signal to use briefly the signal Srepp and the signal Sreca for the tracking. By using the two signals Srepp and Sreca there is guaranteed that at least during part of the readout a suitable tracking error signal is used and a proper tracking is obtained for at least part of the readout of the

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information signal

For reading the information signal, the scanning device may comprise a read circuit 50, an input of which is coupled to an output of an adder circuit 51 for adding together the detector signals 8a and 8b. The read circuit 50 may be one of a customary type described in detail in, for example, EP-A-0.482.964 and non-prepublished Belgian Patent Application no. 9301334 (PHN 14.662), which documents are considered incorporated herein by reference. The information signal read out by read circuit 50 may be applied to a control circuit 52 which detects a code representing the type of record carrier and generates a corresponding control signal Ss.

Fig. 5 shows another embodiment for a circuit for deriving the tracking error signal SRE in which a normalization of the tracking error signal takes place. Depending on the control signal Ss, the derived value of the differential push-pull signal Srepp or the signal Sreca is produced for the signal SRE, while the following relations hold between the signals Srepp and Sreca, on the one hand, and the detector signals S8a, S8b, S9a, S9b, S10a and S10b, on the other:

$$Srepp = \frac{I_1 - I_2}{I_1 + I_2}$$

with $I_1 = S8a + \Gamma/2 (S10b + S9b)$

and $I_2 = S8b + \Gamma/2 (S10a + S9a)$

$$Sreca = \frac{I'_1 - I'_2}{I'_1 + I'_2}$$

with $I'_1 = S9a + S9b$

and $I'_2 = S10a + S10b$.

The device shown in Fig. 5 comprises an arithmetic circuit 60 which derives in customary fashion I_2 from the signals S8b, S10a and S9a. Similarly, I_1 is derived from the signals S8a, S10b, and S9b by means of an arithmetic circuit 61. An arithmetic circuit 62 derives in customary fashion I'_2 from the signals S10a and S10b, whereas an arithmetic circuit 63 similarly derives I'_1 from the signals S9a and S9b. The signals I_2 and I'_2 are applied to a selection circuit 64 controlled by the signal Ss, which circuit 64 presents



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on its output either the signal I_2 or the signal I'_2 in response to the signal S_s . The signal on the output of the selection circuit will hereinafter also be referenced I_2^* .

The signals I_1 and I'_1 are applied to a selection circuit 65 likewise controlled by the control signal S_s . The selection circuit 65 presents on an output either the signal I_1 or the signal I'_1 in response to the control signal S_s . The signal on the output of the selection circuit will be referenced signal I_1^* hereinafter. The signals I_1^* and I_2^* are applied to a normalization circuit of a customary type which derives the signal SRE from I_1^* and I_2^* according to the following relation:

$$SRE = \frac{I_1^* - I_2^*}{I_1^* + I_2^*}$$

Due to the normalization, the tracking error-signal SRE becomes less sensitive to all sorts of parameter variations. For a detailed description thereof reference be made to EP-A-0.512.616.

The advantage of the embodiment shown in Fig. 4 is that the same normalization circuit can be used in the two different operating states. With the scanning device described above it is possible to guarantee a most reliable tracking without adapting the optical system for record carriers having a first and a second track pitch. The track pitch ratio is preferably equal to 1:2. However, also with track pitch ratios of two different types of record carriers within the range between 1.5 and 2.5 achieves stable error tracking with the device according to the invention.

The high reliability of the tracking in the scanning device according to the invention will be further explained hereinafter.

The relation between the signal Srepp and the signal Sreca as a function of the tracking error is given by the following formulas:

$$Sreca = mca \cdot \sin(\phi) \cdot \sin(2\pi x/q) \quad (1)$$

$$Srepp = mcb \cdot (1 - \cos(\phi)) \cdot \sin(2\pi x/q) \quad (2)$$

$$\text{with } \phi = 2\pi x_0/q$$

where mca and mcb denote a modulation depth for the signals concerned,

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where x denotes the tracking error (distance between the centre of a track to be followed and the centre of the main read spot),

where x_0 denotes the shift of the auxiliary read spot relative to the main read spot in a direction perpendicular to the direction of the track, and

where q denotes the track pitch.

As appears from equation 1, the maximum amplitude of S_{reca} is obtained with $\phi = \pi/2$, or for $x_0 = q/4$. In addition, the sensitivity of S_{reca} to variations of ϕ and this value of x_0 is minimized.

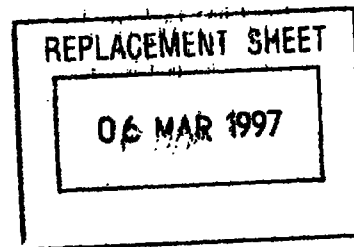
As appears from equation 2, the maximum amplitude of S_{repp} is obtained with $\phi = \pi$, or $x_0 = q/2$. In addition, the sensitivity of S_{repp} to variations of ϕ is minimized with these values of ϕ .

Variations of ϕ are caused, for example, by variations of the position of the read head relative to the direction of the track. These position variations occur when record carriers are read out having, in essence, concentric tracks and for which the point of rotation does not lie exactly in the centre of the concentric tracks, which phenomenon is also referenced eccentricity. Variations in the position of the read head relative to the direction of the track do occur in the case where the angle of the direction of the track to the track along which the read head travels in radial direction is a function of the radial position of the read head.

Due to these variations of ϕ it is merely possible to realise a sufficiently stable tracking control with a limited range of ϕ . In the device according to the invention, both for the scanning of the record carrier shown in Fig. 3 and for the scanning of the record carrier shown in Fig. 4 the amplitude of the tracking error signal is maximum and the sensitivity of the tracking error signal to variations of ϕ is minimum, so that always a highly reliable tracking is obtained.

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Claims:

Scanning device for scanning a record carrier which comprises parallel, optically detectable tracks, the device comprising an optical system for focusing, via the record carrier, a main radiation beam, a first and a second auxiliary radiation beam on a radiation-sensitive main detector, a first and a second auxiliary detector respectively, while the main detector and auxiliary detectors comprise each at least a first and a second sub-detector, the device comprising a tracking control system for controlling, in response to a tracking error signal, a position of a read spot caused by the main radiation beam on the record carrier, which tracking control system can be brought to a first or a second operating state in which tracking control system in the first operating state first generating means for generating tracking error signals are active for generating as a tracking error signal a differential push-pull signal which represents a combination of mutual differences between detector signals from sub-detectors of individual detectors, and which tracking control system comprises second generating means for generating tracking error signals which second generating means are active in the second operating state and differ from the first generating means for generating tracking error signals, characterized in that the second generating means for generating tracking error signals comprise deriving means for deriving as the tracking error signal a signal that represents a difference between the sums of the detector signals of the sub-detectors of the first and of the second auxiliary detector.

2. Device as claimed in Claim 1, wherein the device comprises means for causing the tracking control system to adopt the first or second operating state in response to a selection signal, and control means for deriving the selection signal in response to at least one detector signal supplied by the main detector.

3. Device as claimed in Claim 1, characterized in that the control means control a read circuit for recovering an information signal that corresponds to information recorded on the record carrier, which control takes place in response to said detector signal supplied by the main detector, and means for producing a selection signal in response to a detection of predetermined codes in the information signal, which detection signal corresponds to this code.

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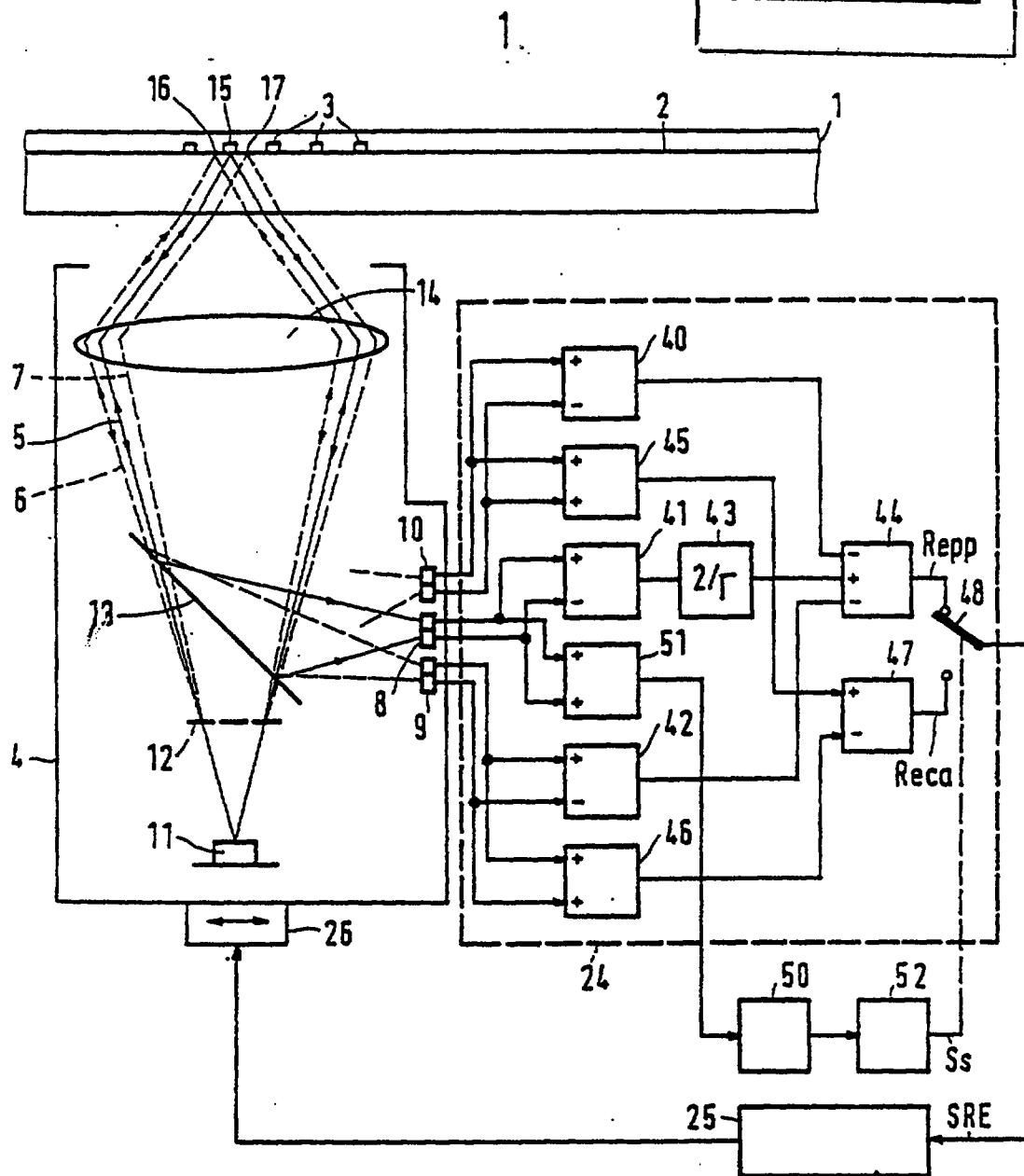
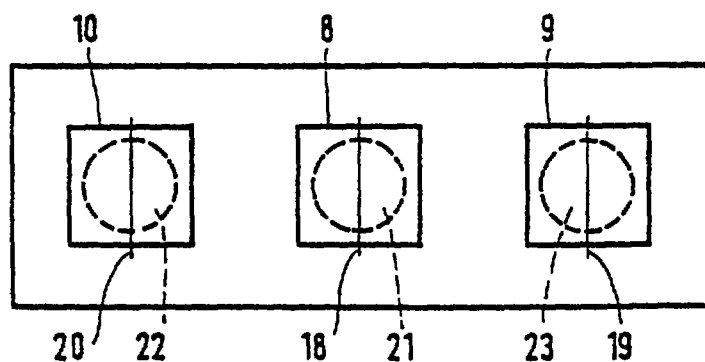


FIG.1



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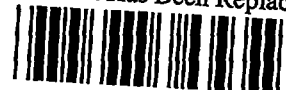


FIG.2

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2.

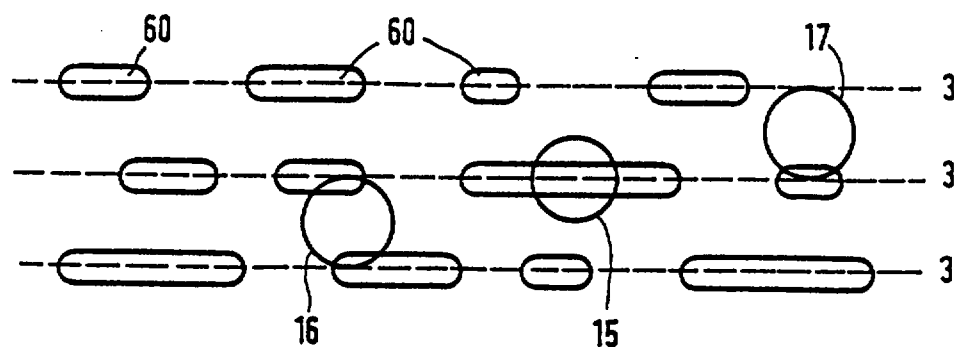


FIG. 3

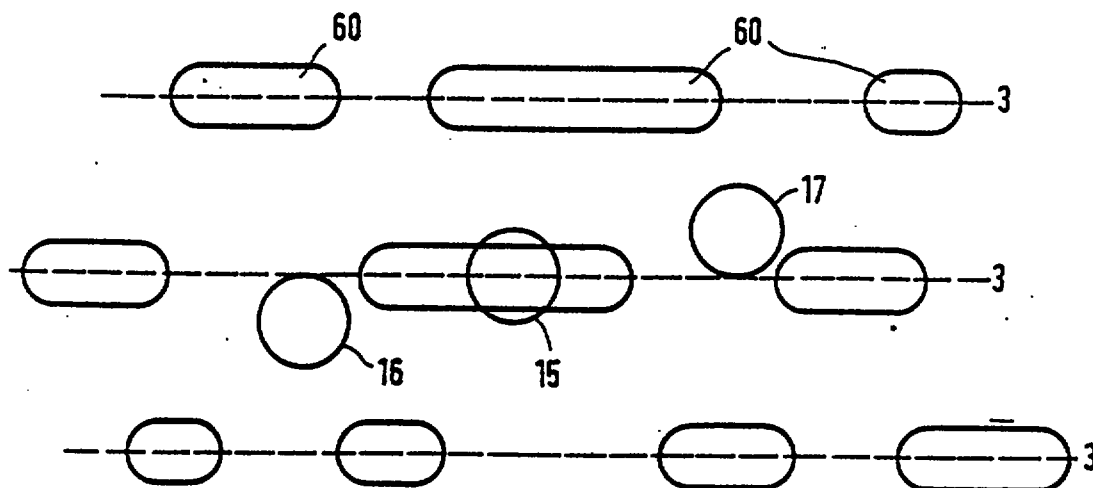


FIG. 4

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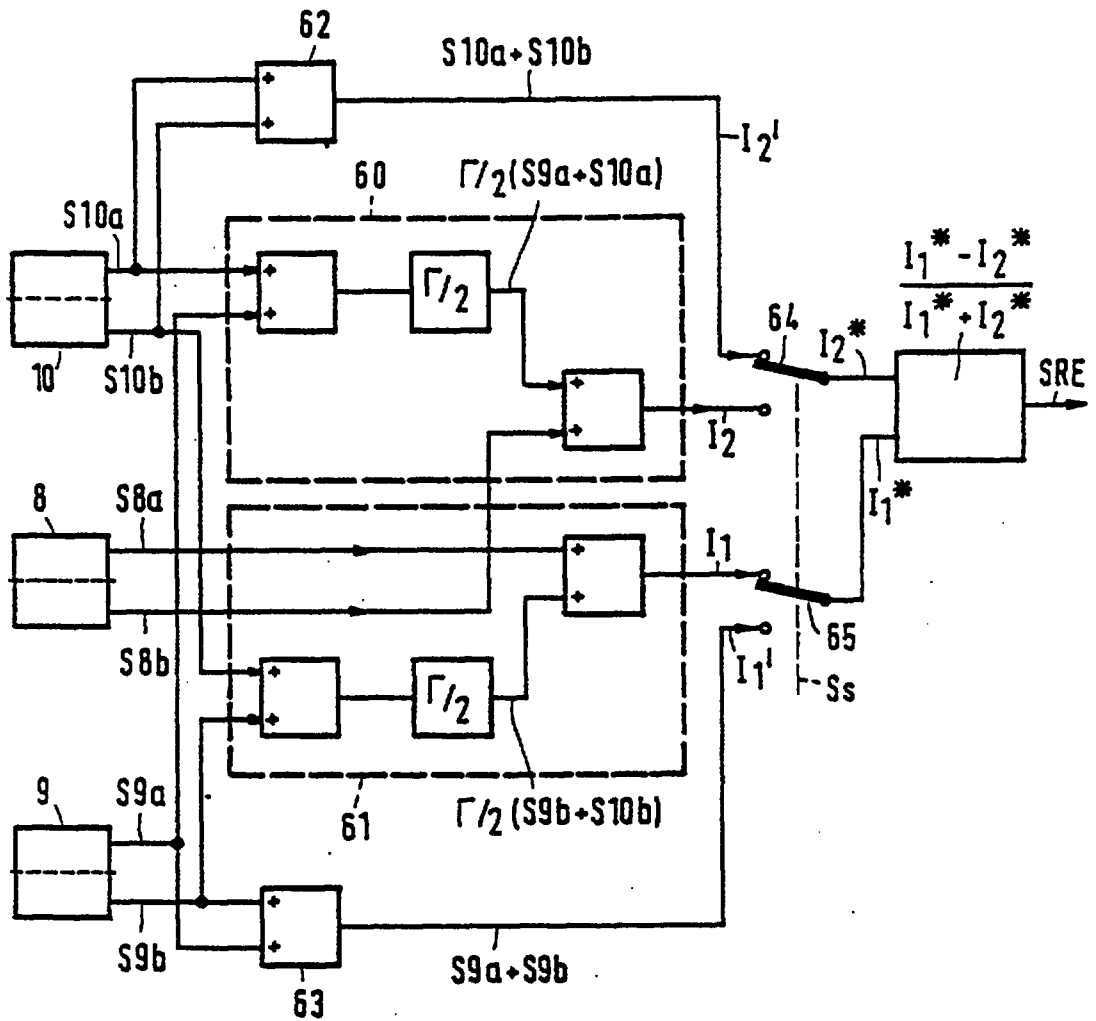


FIG.5

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Abstract:

Optical scanning device.

A scanning device for scanning a record carrier (1) is disclosed which comprises parallel, optically detectable tracks (3). The device comprises an optical system (13, 14) for focusing *via* the record carrier (1) a main radiation beam, a first and a second auxiliary radiation beam on a radiation-sensitive main detector (8), a first auxiliary detector (9) and a second auxiliary detector (10), respectively. The main detector (8) and auxiliary detectors (9, 10) comprise each at least a first and a second sub-detector. A tracking control system (24, 25, 26) controls a position of a read spot (15) caused by the main radiation beam on the record carrier. In a first operating state first generating means (40, 41, 42, 43, 44) for generating a first tracking error signal are used for generating a differential push-pull signal (Srepp) representative of a combination of mutual differences between detector signals from sub-detectors of individual detectors (8, 9, 10) as an error tracking signal (SRE). In a second operating state second generating means (45, 46, and 47) for generating tracking error signals are used for deriving as the tracking error signal (SRE) a signal (Sreca) which is representative of a difference between sums of the detector signals of the sub-detectors of the first (9) and second auxiliary detector (10).

Fig. 1 .

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DESCRIPTION

SIMULATION ARRANGEMENT

The present invention relates to a simulation arrangement and more particularly to a fixed-bed vehicle simulation arrangement in which the operator is not physically moved around by the arrangement.

Fixed bed simulators for training and entertainment purposes such as flight simulators and video games for driving are available at a variety of levels of sophistication. The crudest simulators provide the operator with a view from the vehicle which is merely translated in space relative to the previous view. More sophisticated simulators such as that described in Van Winsum, W., "GIDS Small World Simulation" Chapter 9 in Michon, J.A., "Generic Intelligent Driver Support", Taylor and Francis, London also rotate the view to provide the operator with an objective view from the simulated vehicle. Such simulators provide a much more realistic output to the operator than the crudest types of simulator. However, they are not as realistic (or as expensive) as a full simulator which moves the operator around.

One difficulty that has arisen in the development of a fixed-bed simulator which both rotates and translates the view provided to the operator is that the operator sees a situation that does not correspond to what he feels. This anomaly can cause feelings of nausea in the operator.

It is an object of the present invention to provide a fixed-bed simulation arrangement which results in reduced feelings of nausea in the operator.

According to the present invention there is provided a vehicle simulation arrangement comprising display means for displaying a view from a simulated vehicle to an operator, at least one control device for actuation by an operator, means responsive to the at least one control device for maintaining an objective direction of the simulated vehicle, characterised in that lag means are provided for delaying the objective direction of the simulated vehicle before it is applied to the means for displaying a view from

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the simulated vehicle.

The provision of a delay between the objective direction of the simulated vehicle and the direction of view actually provided to the operator means that the simulation apparatus does not always show the operator a view looking along the vehicle axis as is done in known systems and this is found to be less nausea-inducing. A simulation apparatus in accordance with the invention has also been found to be easier to control.

In order to generate the view to be shown to the operator, two pieces of information are required. These are firstly the calculated position of the vehicle within the simulator's model of the world, and secondly the direction in which the vehicle is pointing. The crude simulators discussed above ignore the direction information completely while the more sophisticated simulators rotate the view to take account of vehicle direction. In the real world, however, or on a moving bed simulator, the driver senses when he is turning and unconsciously turns his eyes to tend to stabilise his direction of view, even when his body is turned. The problem with sophisticated fixed-bed simulators is that part of the sensation of motion is lost and the unconscious stabilisation process cannot work so the field of view appears to change more than it would if the cues which help stabilisation were present.

In the present invention, the perceived change of direction lags relative to the objective direction, and the time constant of the lag is a measure of how quickly the change of direction is perceived. The perceived change of direction is due, in the real world, to imperfection in the eye's stabilisation. The eye's stabilisation system may be assumed to act as a simple lag, with a time constant of 100ms. The turning of the eye therefore lags the objective change in direction by this amount. The perceived change of direction is the difference between the turning of the eye and the objective change of direction. Values used in the simulator may be between, for example 0.05 and 0.25 seconds. The lag means may include differentiation means for providing a view to the display means which is rotated by an amount proportional to the rate of change of objective direction of the simulated vehicle

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For sharp turns of the simulated vehicle, the difference between the objective view and the view provided to the operator may be too great for the simulation to be realistic. To overcome this difficulty a non-linear transfer function may be used whereby for small changes in direction the view direction lags the objective change of direction, but for large changes the full change is passed to the display generator.

Alternatively, where a simulated car is driven on a track, for example, the simulation apparatus may include means to provide a particular course around sharp corners and only the objective vehicle's deviations from this course are applied to the differentiator means and thence to the operator.

The location model of the simulator may conveniently be stored as a series of small blocks. These may be arranged as a standard library of blocks and a sequence listing the order in which the blocks are to be called up

The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a block schematic diagram of a simulation apparatus in accordance with the present invention,

Figure 2 shows a flow chart for the operation of a simulation apparatus,

Figure 3 shows a diagrammatic view of the storage of a road in the simulation apparatus, and

Figure 4 shows the view of Figure 3 transformed into a perspective view from the simulated vehicle.

Referring to Figure 1, the simulation apparatus, for example a car simulator, has one or more controls for actuation by the operator, in this case a steering wheel 10. The steering wheel is arranged to rotate a potentiometer which is connected to an analogue to digital converter (A/D) 12. Other techniques for measuring the position of the steering wheel such as optical or magnetic shaft encoders could be used instead. The A/D 12 provides a digital output which is connected to a model 14 of the vehicle.

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The model of vehicle behaviour is arranged in conventional manner to provide position and direction information according to the characteristics of the simulated vehicle and the operator's use of the controls. Instead of applying an output of the model 14 to a display or display generator, that output is connected to a lag means 16. The lag means 16 includes a differentiator for providing a view to the display means which is rotated by an amount proportional to the rate of change of objective direction of the simulated vehicle. The rate of change of vehicle direction provided at the output of the model 14 determines the amount of change of direction to the subjective vehicle position. If a large rate of change of direction is applied to the means 16 by virtue of the operator turning the steering wheel 10 sharply, a greater direction change is applied to the display. Thus, the display of a sharp turn to the operator will show as a greater change of direction than a more gentle turn and vice versa. A differentiator having a time constant of 100ms has been found to give good results.

The output of the means 16 is connected to a display generator 18 which derives the operator's view from the vehicle from the position information in a conventional manner and provides the view to the display 22. Because of the inclusion of the means 16, the view provided to the operator on the display 22 will differ from the objective axis of the vehicle during and after turning. For simplicity only a steering wheel 10 has been shown and described but it will be understood that the simulation may also comprise a throttle and brake in the manner of known car simulators or more sophisticated controls in the case of a flight simulator and so on.

The display generator 18 is optionally connected to a location model 20 which provides details of a racetrack or other simulated environment in which the vehicle is being operated. The location model 20 may also be connected to the lag means 16 to provide a predetermined course around sharp corners. This predetermined course is subtracted from the objective course and the difference processed by the lag means.

The models 14, 20, the lag means 16 and the display generator 18 may conveniently be implemented by a programmed microprocessor

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arranged to execute the program steps illustrated in Figure 2.

The flow chart steps have the following functions:

- 30 - start
- 32 - set elapsed time to zero
- 34 - read input from operator's controls
- 36 - apply time elapsed and current position to vehicle model
- 38 - derive rate of change of direction term proportional to rate of objective vehicle turning
- 40 - derive subjective direction of view from vehicle from rate of change of direction term and eye stabilisation lag
- 42 - display subjective view from vehicle
- 44 - increment elapsed time

This second embodiment of the invention operates in a similar manner to the first embodiment to provide the operator with a view from the vehicle whose direction lags by an amount according to the rate of change of objective vehicle turning.

The location model, or image which the operator of the simulation apparatus sees, may be provided in the following manner which is particularly suitable for implementing on a microprocessor which has limited processing speed or limited memory, such as a personal computer.

Figure 3 shows a plan view of a portion of a road 50 upon which the simulated vehicle is to be driven and this road is shown divided into 10 blocks 52, 54, 56, 58 and 60. The same numbered blocks represent the same road pattern. The road 50 may be stored as a number of individual blocks or as a library of standard blocks and a sequence of reference numbers which specify the order in which blocks are selected from the library of standard blocks. The former option allows greater freedom of design and may be marginally faster but the latter will generally save a large amount of storage space with a minimal sacrifice of flexibility. In use the standard blocks may be retrieved simply by specifying their reference number. Thus a large road layout or racetrack may be stored as a number of

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short identity codes. The road layout within the blocks may be stored as a number of pixel values for the left and right of the road or as a value for one side of the road and a width measurement. To ensure that the road matches up with that of an adjacent block, an offset value may be included in each block which is applied to displace the following block relative to it. While ten blocks are shown in the figure, in practice a larger number of the order of 50 or more will be used to provide a reasonable level of realism. Each block will then represent of the order of a metre of actual road. For increased realism blocks relating to approximately 10 cm of actual road may be used.

To provide a perspective view of the road to an operator of the simulation apparatus, the following transformation is performed. The identity numbers of the relevant blocks for the present position of the vehicle are read out and their respective layout data is retrieved. The closest block will be displayed in the greatest detail and the furthest block will displayed in the least detail, typically as a single line of pixels on the screen only. The relation between the plan of each block and the image on the screen thus depends upon the distance of the block from the simulated vehicle. There now exists the possibility of a tradeoff between processing power and amount of memory available to the processor. If processing power is limited but memory is relatively plentiful the image of the road ahead for each block may instead be stored as a number of perspective views dependent upon the distance from the simulated vehicle. The relevant view for that portion of the road is then simply recalled on the basis of distance from the simulated vehicle. If memory is more limited, however, the perspective views can be derived from the plan views using simple interpolation techniques and narrowing of the road as it approaches the vanishing point in the distance. In either case the result should be as shown in figure 4 where the perspective view 50' of the road is displayed on a screen 70 and vanishes at the horizon 72. The blocks are labelled with dashed numbers which correspond to those in Figure 3. The four blocks of road labelled 52' nearest the operator thus become progressively shorter and narrower as their distance from the simulated vehicle increases. The blocks of the perspective

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road 50' that are still further away are shorter and narrower. To derive the perspective version of a block from the plan view version it is sufficient to shorten and narrow the block dependent upon the distance from the simulated vehicle but for improved realism when sufficient processing power is available, more sophisticated transforms may be used as are known in the simulator art, for example from 'Computer Graphics Principles and Practice' by Foley, van Dam, Feiner and Hughes and published by Addison-Wesley. Where the simulator provides a predetermined course along the road from which the perceived direction of view is derived, this may conveniently be stored in the location model blocks.

Next the heading of the simulated vehicle on the road is derived from the vehicle model, for example from the past heading of the vehicle, the position of the operator's steering wheel and any other factors such as wheel slip which depend upon the sophistication of the simulator. The direction in which the road ahead is pointing (in other words since the operator is inside the simulated vehicle, it is the road that is seen to move when the vehicle turns) is then derived and displayed. To conserve computing power it is possible to adjust the direction of the road on the screen using a shear transform provided in the display hardware where such a transform is available. Similarly, the horizontal location of the road relative to the vehicle may be adjusted by a linear transformation or left-right hardware scroll. The simulation then repeats these steps to derive the next view to be provided to the operator.

While a car simulation apparatus has been described it will be understood that the invention may be applied to simulators for aeroplanes, boats, motorcycles and so on. Where a simulator in accordance with the invention is used to simulate an aeroplane or other vehicle which has freedom to move up and down as well as left to right, a lag may also be applied to changes of elevation angle as well as changes of heading.

From reading the present disclosure other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the design, manufacture and use of

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vehicle simulators and component parts thereof and which may be used instead of or in addition to features already described herein. Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure of the present application also includes any novel feature or any novel combination of features disclosed herein either explicitly or implicitly or any generalisation thereof, whether or not it relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as does the present invention. The applicants hereby give notice that new claims may be formulated to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

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CLAIMS

1. A vehicle simulation arrangement comprising display means for displaying a view from a simulated vehicle to an operator, at least one control device for actuation by an operator, means responsive to the at least one control device for maintaining an objective direction of the simulated vehicle, characterised in that lag means are provided for delaying the objective direction of the simulated vehicle before it is applied to the means for displaying a view from the simulated vehicle.

2. A simulation apparatus as claimed in Claim 1, wherein the lag means has a time constant of between 0.05 and 0.5 seconds.

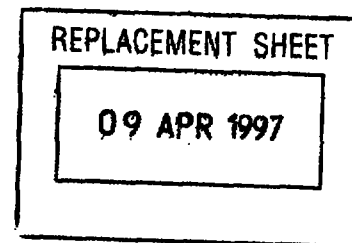
3. A simulation apparatus as claimed in Claim 1 or Claim 2, wherein the lag means includes differentiation means for providing a view to the display means which is rotated by an amount proportional to the rate of change of objective direction of the simulated vehicle.

4. A simulation apparatus as claimed in Claim 1, Claim 2 or Claim 3, further comprising means for providing a predetermined course and means for subtracting the predetermined course from the objective course to provide a difference course to the lag means.

5. A simulation apparatus as claimed in any one of the Claims 1 to 4, further comprising means for storing a plurality of location model blocks arranged for display in sequence.

6. A simulation arrangement as claimed in any one of the Claims 1 to 4, further comprising means for storing a plurality of location model library blocks, means for storing at least one sequence of library blocks and means for reading library blocks in accordance with the stored sequence.





7. A simulation arrangement as claimed Claim 5 or Claim 6, wherein the location model blocks comprise a plan representation of the location model, the arrangement further comprising transform means for converting the representation of the location model to a view from the simulated vehicle.

8. A simulation arrangement as claimed in Claim 5 or Claim 6, wherein each of the location model blocks contains at least one representation of the location model as viewed from the simulated vehicle.

9. A simulation arrangement as claimed in Claim 8, wherein each of the location model blocks contains a plurality of representations of the location model at different distances as viewed from the simulated vehicle.



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ABSTRACT

SIMULATION ARRANGEMENT

A vehicle simulator is provided with a control device (10) for actuation by an operator which device's input is digitised (12) and fed to a vehicle model (14). The model (14) maintains an objective position and direction for the simulated vehicle which are fed to a lag means (16). The lag means operates to delay the rate of change of objective direction of the simulated vehicle to provide a subjective direction to a display generator (18). The display generator (18) provides a subjective view based on the objective position and subjective direction of the simulated vehicle on a display (22).

(Figure 1)

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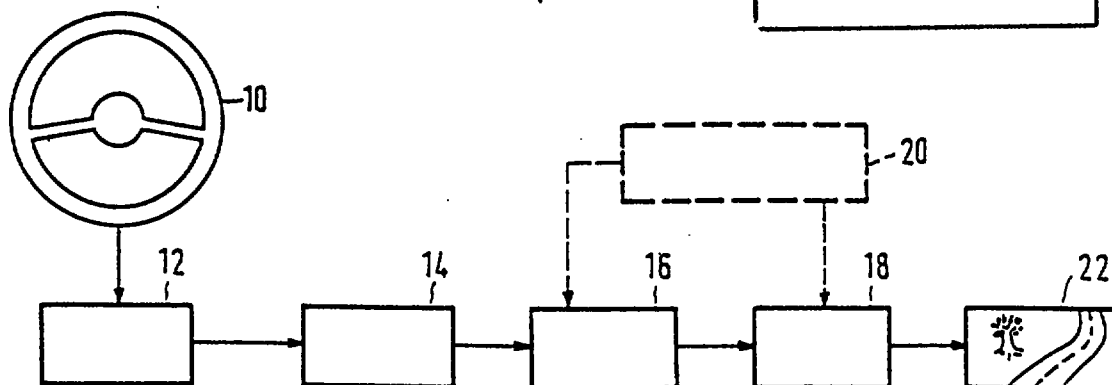


FIG.1

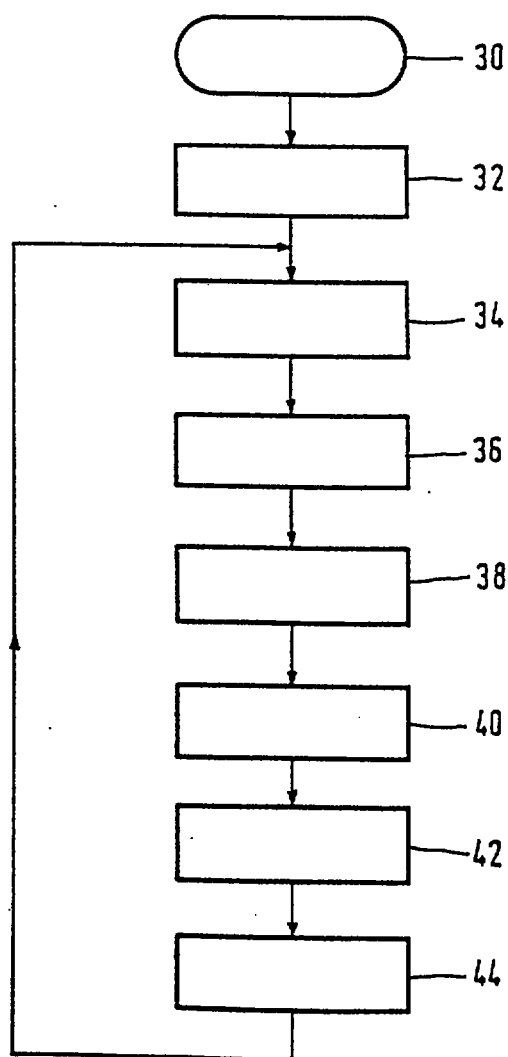


FIG.2

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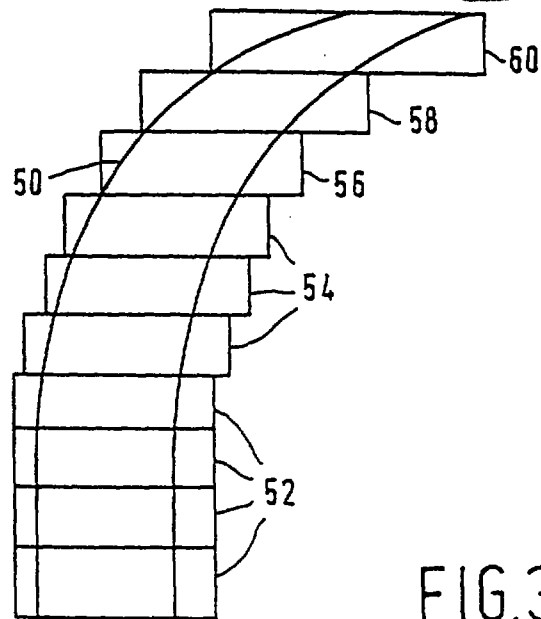


FIG. 3

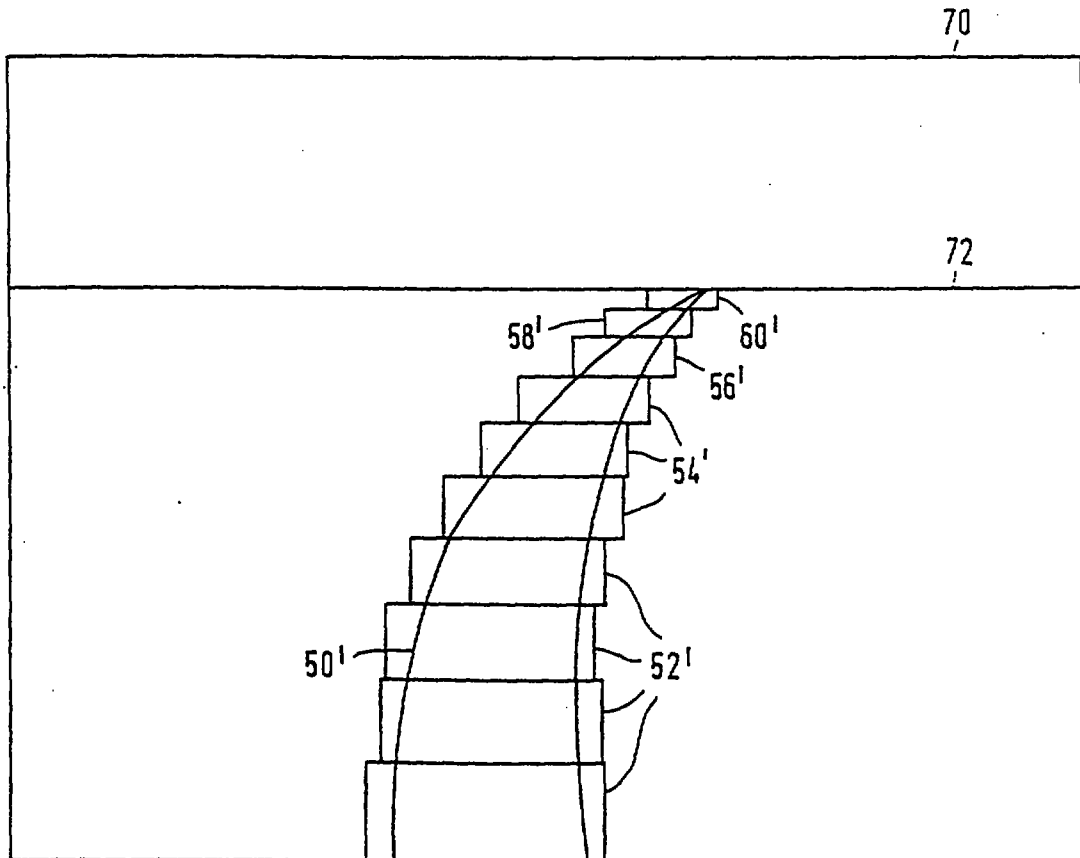


FIG. 4