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(54)   **Method and device for measuring the angular position of an emitting or reflecting object with hyperacuity**

(57)   The invention concerns a method for measuring the relative angular position of an object (E) and an angular position measuring device (10) comprising at least a first and a second transducers (D1, D2) delimiting respectively a first and a second reception fields, the first and second reception fields overlapping in area defined as the field of view of the device (10), the method comprising the following steps:
a) carrying out an amplitude modulation of the signals delivered by the first and the second transducers (D1, D2); and
b) calculating an output signal (A) starting from the amplitude modulated signals (Ph1, Ph2) delivered by the first and the second transducers (D1, D2) as a function of said relative angular position,

characterized in that step a) is done by receiving radiation (M), whose intensity is modulated in time at a known frequency, from said object (E) with said transducers (D1, D2) within the field of view.
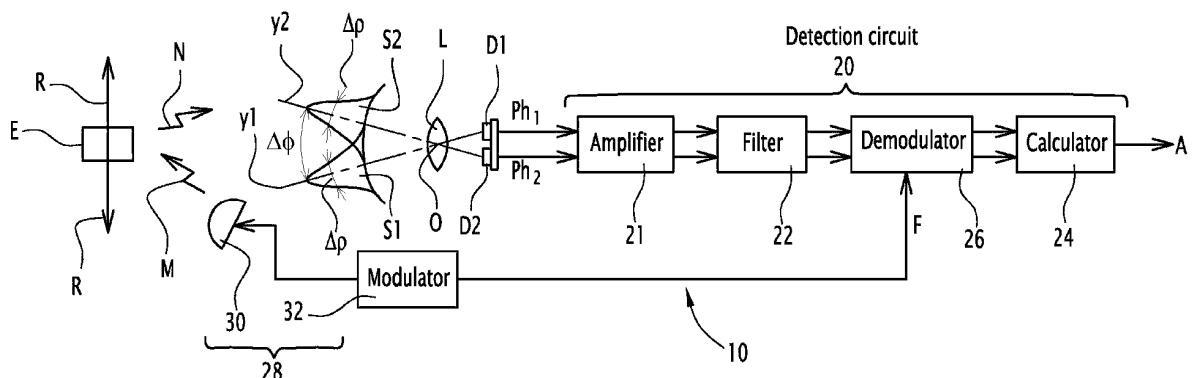
FIG.1

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Description

[0001] The present invention relates to a method for measuring the relative angular position of an object and an angular position measuring device comprising at least a first and a second transducers delimiting respectively a first and a second reception fields, the first and second reception fields overlapping in an area defined as the field of view of the device, the method comprising the following steps:

a) carrying out an amplitude modulation of the signals delivered by the first and the second transducers ; and
b) calculating an output signal starting from the amplitude modulated signals delivered by the first and the second transducers as a function of said relative angular position.

[0002] The present invention also relates to a device for measuring the relative angular position of an object and said device, the device comprising:

- at least a first and a second transducers delimiting respectively a first and a second reception fields, the first and second reception fields overlapping in an area defined as the field of view of the device ; and
- a detection circuit comprising a means for calculating an output signal starting from the signals delivered by the first and the second transducers as a function of said relative angular position.

[0003] Such a method and device are known from EP 2 341 312 A1. In this known device and method, the amplitude modulation of the signals delivered by the transducers is achieved by mechanical vibration of the transducers. Accordingly, this known solution requires a mechanical actuator for vibrating the transducers.
[0004] However, this mechanical actuator needs to be carefully designed. Furthermore, it is subject to stresses and wear leading to malfunctions or even break-down.
[0005] Thus, an object of the present invention is to make the method and device of EP 2 341 312 A1 more reliable, cheaper, simpler and capable to detect a punctual object or a bar type object.
[0006] According to the invention, in the method detailed above, this object is achieved in that step a) is done by receiving radiation, whose intensity is modulated in time at a known frequency, from said object with said transducers within the field of view.
[0007] Likewise, according to the invention, in the device detailed above, this object is achieved by the device further comprises a radiation source adapted to emit radiation, whose intensity is modulated in time at a known frequency, towards said object such that said radiation is reflected from said object into said field of view.
[0008] Hence, in the present invention, the mechanical vibration is replaced by intensity-modulated radiation. Such radiation is generated more easily than a mechanical vibration and there are no mechanical parts that might malfunction. Due to the absence of a mechanical actuator, the inventive method and device are also cheaper.
[0009] According to preferred embodiments, the method of the invention has one or several of the following features, taken in isolation or in all technically possible combinations:

- the method comprises the step of illuminating said object with a radiation such that said reception of said radiation occurs by reflection from said object into said field of view.
- the method comprises the step of illuminating the object with a plurality of radiations having the same wavelength and synchronised such that said reception of said radiation occurs by reflection from said object of the into said field of view.
- said object is a radiation source emitting said radiation.
- said object comprises a plurality of radiation sources emitting said radiation.- the output signal is the difference-to-sum ratio of the amplitudes of the temporally filtered signals delivered by the first and the second transducers.
- the output signal is proportional to the difference between the logarithm of the absolute value of the temporally filtered signal delivered by the first transducer and the logarithm of the absolute value of the temporally filtered signal delivered by the second transducer.
- the method comprises a step of demodulation of the signals delivered by the first and the second transducer before the step of calculating the output signal, the output signal being calculated starting from the demodulated signals.
- the demodulation is an asynchronous demodulation, a synchronous demodulation or an envelope detection of the signals delivered by the first and the second transducers.
- the demodulation involves a step of filtering the signals delivered by the first and the second transducer, said filtering being a selective filtering centered on said known modulation frequency.
- the demodulation involves a step of filtering the signals delivered by the first and the second transducer, said filtering being a derivative filtering.
- the demodulation involves a step of filtering the signals delivered by the first and the second transducer, said filtering

being a combination of both a selective filtering centered on said known modulation frequency and a derivative filtering.

- said transducers are optical sensors, such as photoelectric sensors, and said radiation is optical radiation, such as infrared radiation.

- each transducer has an angular sensitivity function with a spatial shape that can be approximated by a spatial Gaussian shape characterized by a variance, the shape being characterized by an angle at half-width proportional to the square root of the variance of the Gaussian shape.

[0010]   The invention is also directed to a method for measuring the relative angular position of each of a plurality of objects and an angular position measuring device comprising at least a first and a second transducers delimiting respectively a first and a second reception fields, the first and second reception fields overlapping in an area defined as the field of view of the device, wherein the method as previously described is carried out for each of said objects, each object being associated with a specific radiation having its own unique modulation frequency.

[0011]   According to preferred embodiments, in such method for measuring, each transducer has an angular sensitivity function with a spatial shape that can be approximated by a spatial Gaussian shape characterized by a variance, the shape being characterized by an angle at half-width proportional to the square root of the variance of the Gaussian shape.

[0012]   According to preferred embodiments, the device of the invention has one or several of the following features, taken in isolation or in all technically possible combinations:

- a lens having a lens center, the first and second transducers being placed substantially in the image focal plane of the lens and the average directions of observation of the first and second transducers corresponding substantially to two lines linking the centers of the first and second transducer and the lens center of the lens.

- the detection circuit comprises a demodulator for demodulating the signals delivered by the first and the second transducers.

- said transducers are optical sensors, such as photoelectric sensors, and said radiation source is an optical radiation source, such as an infrared source.

- each transducer has an angular sensitivity function with a spatial shape that can be approximated by a spatial Gaussian shape characterized by a variance, the shape being characterized by an angle at half-width proportional to the square root of the variance of the Gaussian shape.The invention is also directed to a set of devices comprising at least one lens, at least three transducers and a plurality of detection circuits, each pair of two consecutive transducers being placed close to the focal plane of one of the at least one lens and connected to one of the plurality of detection circuits, wherein at least one device as previously described includes one of the at least one lens, and wherein each lens of the at least one lens and each transducer are arranged substantially on a spherical, cylindrical or curved surface surrounding at least one local common centre, the at least

one local common centre constituting the centre of field of view which is the sum over all fields of view of each of the devices taken together.

[0013]   The invention will be better understood when reading the following description of non limiting examples of the invention, with reference to the accompanying figures, wherein:

Figure 1 is a schematic representation of a first embodiment of the inventive angular position measuring device;
Figure 2 is a schematic representation of a second embodiment of the inventive angular position measuring device;
Figure 3 is a schematic representation of a third embodiment of the inventive angular position measuring device;
Figure 4 is a schematic representation of a fourth embodiment of the inventive angular position measuring device;
Figure 5 is a schematic representation of a fifth embodiment of the inventive angular position measuring device ; and
Figure 6 is a graph showing the detector's output signal in response to the movement of a finger in the first embodiment of the inventive angular position sensing device.

[0014]   With reference to figure 1, there is shown a first embodiment 10 of an inventive angular position measuring device. The angular position measuring device 10 is adapted to measure, as a function of time and in 1 dimension, the angular position Ψ of a moving object E with respect to said angular position measuring device 10. The movement of the object E is illustrated by the arrows R.

[0015]   The device 10 for measuring the angular position comprises a first transducer a second transducer, namely optical sensors D_1 and D_2 whose optical axes Y_1, Y_2 are separated by an inter-receptor angle $\Delta\varphi$. Such angle is non zero. In other words, it can be defined for each detector D1, D2 a reception field, respectively the first and the second one. Such reception fields overlap. The overlapping area is defined as the field of view FOV of the device 10.

[0016]   Preferably, the first and the second optical sensors D_1 and D_2 are each formed by a photoelectric receiver such as a photoelectric diode, whose spectral sensitivity can be selected in the spectral range of visible or ultraviolet light or,

alternatively, in the range of near or far infrared radiation - for example for nocturnal or all-weather conditions.

[0017] The wavelength of maximum sensitivity of the aforementioned photodiodes can thus be chosen in dependence of the specific application of the angular position measuring device 10.

[0018] Preferably, the angular position measuring device 10 also comprises a convex lens L, which determines said inter-receptor angle $\Delta\varphi$. The optical sensors D_1 and D_2 are placed substantially in the focal plane of the lens L. The optical center O of the lens L is located between the optical sensors D_1, D_2 and the object E. The optical axes Y_1, Y_2 of the first and second optical sensors D_1, D_2 correspond substantially to the lines linking the centers of the first and second optical sensors, respectively, and the optical center O of the lens L.

[0019] The lens L placed in front of the two optical sensors confers them a given angular sensitivity. The corresponding angular sensitivity function S is a Bell-shaped (Gaussian-like) function, as shown in the figures. The Gaussian-like angular sensitivity function S is obtained by slightly defocusing the system consisting of the lens L and the optical sensors, whereby the two optical sensors D_1 and D_2 are placed close to the focal plane, between the lens L and its focal plane. The angular sensitivity functions S_1, S_2 of the two optical sensors D_1 and D_2 are partially overlapping (cf. the figures). The optical axes Y_1 and Y_2 correspond to the maximum sensitivity of each of the optical sensors D_1 and D_2, respectively.

[0020] The position of the object E is defined by two angles ψ and θ. In this case, the two-dimension angular sensitivity function $s(\psi, \theta)$ of the first and second optical sensors D_1 and D_2 can be written as follows:

$$s(\psi,\theta) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{\psi^2+\theta^2}{2\sigma^2}}$$

[0021] The parameter σ is defined by the full width at half maximum (FWHM) $\Delta\rho$ of the angular sensitivity function (cf. the figures) and results directly from the variance σ^2 of the Gaussian curve by the following formula:

$$\frac{\Delta\rho}{2\sqrt{2\ln 2}} = \sigma$$

[0022] According to this formula, the full width at half maximum is the square root of the variance σ^2.

[0023] It is to be noted that the just described Gaussian-like angular sensitivity is merely exemplary. The optical sensors' angular sensitivity can also take a different form, such as a cosine form. Moreover, in one embodiment, the detector 10 can only comprise two optical sensors D_1 and D_2 without the lens L. In this embodiment, the Gaussian-like angular sensitivity function is being provided by the own angular sensitivity function of the optical sensors.

[0024] Typical optical characteristics of the device 10 are: $\Delta\rho$ = 3° and $\Delta\varphi$ = 2.87°, which gives a ratio $\Delta\rho$: $\Delta\varphi$ of 1.04.

[0025] Moreover, the device for measuring the angular position 10 comprises a detection circuit 20 in order to determine the angular position ψ of the object E, on the basis of the signals Ph_1 and Ph_2 delivered by the first and the second optical sensors D_1 and D_2, respectively. The detection circuit 20 is connected to the first and second optical sensors D1 and D2 and receives the signals $Ph_1(t)$ and $Ph_2(t)$ delivered by the first and second optical sensors D_1 and D_2, respectively.

[0026] The detection circuit 20 preferably includes a pair of amplifiers 21 for amplifying the signals $Ph_1(t)$ and $Ph_2(t)$ delivered by the first and second optical sensors D_1 and D_2. The amplifiers 21 may be linear amplifiers or non-linear amplifiers, such as logarithmic amplifiers.

[0027] The detection circuit 20 also comprises a pair of band-pass filters 22 (preferably analog circuits) in order to calculate the differentiated signals of the first and second optical sensors, D1 and D2 respectively.

[0028] Moreover, the detection circuit 20 comprises a calculator 24 for calculating an output signal A and the angular position ψ of the object E depending on the output signal A.

[0029] Furthermore, the detection circuit 20 comprises advantageously a pair of demodulators 26 connected between the band-pass filters 22 and the calculator 24, in order to demodulate the signals delivered by the first and the second optical sensors D_1, D_2 before calculating the output signal A and the angular position Ψ. The demodulation of these two signals enables to extract the information of amplitude of these two signals from noise. The amplitude of the differentiated signals is determined using the pair of demodulators 26. The demodulated signals are then used for the calculation of the output signal A.

[0030] For further details on the detection circuit 20 and its components, reference is made to EP 2 341 312 A1, the corresponding disclosure of which is hereby incorporated into the present description.

[0031] Additionally, the angular position measuring device 10 includes a radiation generator 28. The radiation generator 28 comprises a radiation source 30 and preferably also a radiation intensity modulator 32. The radiation intensity mod-

ulator 32 is connected to the demodulators 26 of the detection circuit 20. The radiation source 30 may be an electrolu-
minescent device, such as a light emitting diode (LED). In this case, the radiation intensity modulator 32 is adapted to
vary the supply voltage of the LED 30 as a function of time. Alternatively, the radiation source 30 may also be a laser.
Preferably, the radiation source 30 is an infrared source.

[0032] A description of the method for measuring the angular position Ψ of the object E using the angular position
measuring device 10 of figure 1 will now be given.

[0033] The modulator 32 controls the radiation source 30 such that the latter emits radiation M towards the moving
object E whose intensity is modulated in time at a given frequency F. One may therefore qualify the radiation source 30
as a scintillating radiation source. Preferably, the frequency F is constant in time. The intensity modulation may for
example be sinusoidal. Frequency F is outputted by the modulator 32 to the demodulators 26.

[0034] The radiation M is reflected by the object E as radiation N, which is received by the optical sensors D_1 and D_2
within the field of view.

[0035] The ensuing signals delivered to the detection circuit 20 by the first and second optical sensors D_1 and D_2 as
a function of time t are denoted by $Ph_1(t)$ and $Ph_2(t)$ and, in the case of an angular position measurement in 1 dimension
(1d), can be written as follows:

$$Ph_1(t) = Lum(t) * s_1^{1d}(\Psi, \theta)$$

$$= Lum(t) * \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{\left(\Psi - \frac{\Delta\varphi}{2}\right)^2 + \theta^2}{2\sigma^2}}$$

$$Ph_2(t) = Lum(t) * s_2^{1d}(\Psi, \theta)$$

$$= Lum(t) * \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{\left(\Psi + \frac{\Delta\varphi}{2}\right)^2 + \theta^2}{2\sigma^2}}$$

[0036] The function Lum(t) represents the luminance of the object E, which varies according to the intensity modulation
applied to the radiation emitted by the radiation source 30.

[0037] The signals $Ph_1(t)$ and $Ph_2(t)$ entering the detection circuit 20 are first amplified by the amplifiers 21.

[0038] Each of the signals from the optical sensors D_1 and D_2 is then filtered in order to extract their dynamical part
by the pair of band-pass filters 22.

[0039] Part of the band-pass filters 22 essentially acts as a temporal differentiator of the signals delivered by the first
and second optical sensors D_1 and D_2. The band-pass filters 22 also cancel the DC component and the high frequency
noise, while acting as anti-aliasing filters for the subsequent digital processing.

[0040] Then, the pair of demodulators 26 isolates the envelope of the differentiated signals.

[0041] The output signal A is calculated by the calculator 24 using the demodulated signals. The desired output signal
A should depend only on the angular position ψ of the object E within the field of view FOV.

[0042] According to the invention, the calculator 24 may calculate the output signal A in two different ways:

[0043] In the first way, the output signal A is the result of the difference-to-sum ratio of the amplitudes of the temporally
differentiated signals:

$$A = \left(\frac{Ph_1(t) - Ph_2(t)}{Ph_1(t) + Ph_2(t)}\right) = \tanh\left(\psi * \frac{4\ln(2)\Delta\varphi}{\Delta\rho^2}\right)$$

[0044] Here, use has been made of the known mathematical equation:

$$\tanh\left(\frac{1}{2}\ln\left(\frac{x}{y}\right)\right) = \frac{x-y}{x+y}$$

where x and y have been replaced respectively by $Ph_1(t)$ and $Ph_2(t)$.

[0045]   The calculation of such ratio allows for the reduction of the common mode noise originating, e.g., from ambient artificial light (100 Hz and higher harmonics, if the frequency of the mains is 50 Hz).

[0046]   As one can see, when this calculation way is used, the output signal A gives a measure of the angular position ψ of the object E since the output signal A is essentially the hyperbolic tangent of the angular position ψ. The advantage of this calculation method is a very good linearity over a large measurement range.

[0047]   Alternatively, the output signal A may be calculated on the basis of the difference between the logarithm of the absolute value of the temporally filtered signal $Ph_1(t)$ delivered by the first optical sensor D1 and the logarithm of the absolute value of the temporally filtered signal $Ph_2(t)$ delivered by the second optical sensor D2. The corresponding equation is as follows:

$$A = \frac{\Delta\rho^2}{8\ln(2)\Delta\varphi}\left(\ln\left|Ph_1(t)\right| - \ln\left|Ph_2(t)\right|\right) = \psi$$

[0048]   In this case, the output signal A is directly equal to the angular position ψ of the object E.

[0049]   Alternative embodiments of the invention will now be described with reference to figures 2 to 5. Regarding elements of these alternative embodiments that are identical or similar to those of the first embodiment of figure 1, reference is made to the description above. In the following, only the differences of the alternative embodiments with respect to the first embodiment will be detailed.

[0050]   Referring now to figure 2, there is shown a second embodiment of an inventive angular position measuring device 12. In contrast to the device 10 according to the first embodiment, this angular position measuring device 12 is able to measure the angular position of two different moving objects E1 and E2, object E1 moving according to arrows R1, and object E2 moving according to arrows R2. To achieve this, the angular position measuring device 12 is equipped with two radiation sources 301, 302.

[0051]   Radiation source 301 emits radiation M1 which is intensity modulated at a first frequency F1. The radiation M1 is reflected by object E1 as radiation N1 into the field of view FOV of the optical sensors D1, D2.

[0052]   Radiation source 302 emits radiation M2 which is intensity modulated at a second frequency F2, different from the first frequency F1. The radiation M2 is reflected by object E2 as radiation N2 into the field of view FOV of the optical sensors D1, D2.

[0053]   With the frequencies F1 and F2 as an input, and using the principles already described for the first embodiment, the detection circuit 20 is able to deliver two output signals A and B, which represent the angular position of the first and second moving object E1, E2, respectively.

[0054]   Referring now to figure 3, there is shown a third embodiment of an inventive angular position measuring device 14. The angular position measuring device 14 comprises a moving sensor assembly 36. The sensor assembly 36 includes a lens L, optical sensors D1, D2 and a detection circuit 20. The translational and/or rotational movement of sensor assembly 36 is illustrated by arrows R. In contrast to sensor assembly 36, the radiation source 30 of angular position measuring device 14 is stationary. Radiation source 30 emits radiation M, which is intensity modulated at a frequency F.

[0055]   Stationary reflectors 34 are provided, which reflect the radiation M as radiation N into the field of view FOV of the optical sensors D1, D2.

[0056]   With the frequency F as an input, and using the principles already described for the first embodiment, the detection circuit 20 is able to deliver an output signal A, which represents the angular position of the sensor assembly 36 with respect to the stationary reflectors 34.

[0057]   Referring now to figure 4, there is shown a fourth embodiment of an inventive angular position measuring device 16. Here, the angular position measuring device 16 lacks a radiation source. Indeed, in this implementation there is no need for providing the angular position measuring device with a radiation source since the moving object E is itself the radiation source. The moving object E whose angular position is to be determined emits radiation M that is intensity modulated by a modulator 32 at a known frequency F. Radiation M enters the field of view FOV of the optical sensors D1, D2. Using the known frequency F, the detection circuit 20 then delivers an output signal A, which is representative of the angular position of the moving radiation source E.

[0058]   Referring now to figure 5, there is shown a fifth embodiment of an inventive angular position measuring device

18. This embodiment is similar to the fourth embodiment of figure 4, with the difference that the angular position measuring device 18 is able to determine the angular position of three moving radiation sources E1 to E3. Moving radiation sources E1 to E3 emit radiation M1 to M3, respectively, into the field of view of the optical sensors D1, D2. Each radiation M1 to M3 is intensity modulated by a corresponding modulator 321, 322 and 323 at a corresponding frequency F1, F2 and F3. The frequencies F1 to F3 are all different from each other. Using the known frequencies F1 to F3, the detection circuit 20 delivers three output signals A, B, C, which represent the angular position of the first, second and third moving radiation source E1, E2 and E3, respectively. The radiations M1 to M3 are at the same wavelength and synchronized. In this context, two radiations are synchronized if there is a temporal relation between the two radiations.

[0059]   According to a further embodiment, which is absent from the figures, several devices for measuring the angular position can be arranged in a set of devices, in order to increase the total field of view of the detection device until it is rendered panoramic. The set of devices comprises at least one lens, a plurality of N optical sensors (N being an integer and N ≥ 2) placed substantially in the focal plane of the lens and (N-1) detection circuits as described before. Each pair of consecutive optical sensors is connected to a detection circuit to calculate a plurality of output signals $A_{(N)}(t)$. The output signal delivered by each detection circuit can thus be sampled for subsequent digital processing. The method as described before is applied to each pair of optical sensors to measure the angular position of an object E.

[0060]   The plurality of optical sensors can be placed substantially in the focal plane of a single lens, the so-called "camera eye" configuration. Alternatively, one or several pairs of consecutive optical sensors can be placed in the focal plane of one of several lenses. Such a set of devices comprises a plurality of adjacent devices, each consisting of a lens and a plurality of optical sensors with different optical axes, the so-called "compound eye" configuration.

[0061]   In the compound eye configuration, the devices are arranged substantially on a spherical or cylindrical surface surrounding a common centre. This common centre constitutes, for the set of devices, the optical centre of an inter-receptor angle $\Delta\varphi$ which is the sum over all inter-receptor angles $\Delta\varphi_i$ of each of the devices taken together. This determines a total filed of view FOVt which corresponds to the sum over all fields of view FOVi of each of the devices taken together.

[0062]   Furthermore, this set of devices can be generalized for detecting a target in two-dimension. In the following example of such a two-dimensional detection, the number of optical sensors is limited to three, D_1, D_2 and D_3, in order to facilitate the description. In one embodiment, the two pairs of optical sensors, D_1-D_2 and D_2-D_3, are arranged in two directions substantially orthogonal H and V. Each pair of optical sensors is placed substantially in the focal plane of its own lens or all the optical sensors are placed in the focal plane of a single lens. Each lens and each optical sensor are arranged substantially on a spherical or cylindrical surface surrounding at least one common centre. A first centre constitutes the optical centre of an inter-receptor angle $\Delta\varphi_H$, in the first direction, and a second centre, which can be identical to the first one, constitutes the optical centre of an inter-receptor angle $\Delta\varphi_V$, in the second direction, substantially orthogonal to the first direction.

[0063]   In the same manner as before, each pair of optical sensors is connected to a detection circuit to calculate two output signals $A_{(H)}(t)$ and $A_{(V)}(t)$, each output signal depending on the angular position Ψ, θ of the target along directions H and V, respectively.

[0064]   In another embodiment, the two pairs of optical sensors, D_1-D_2 and D_2-D_3 are arranged such that $D_1D_2D_3$ form a triangle.

[0065]   Finally, in a non-limiting embodiment, the plurality of optical sensors is arranged according to a matrix of optical sensors, each optical sensor constituting a pixel D_{ij}. The rectangular matrix of optical sensors made up in this way forms a two-dimensional retina.

[0066]   In the preceding description, the invention has been described in the context of electromagnetic and in particular optical radiation. However, the invention may also be carried out using other types of radiation, such as acoustic radiation. In this case, the transducers D1, D2 would take the form of microphones and the radiation source 30 would be a loudspeaker.

Example

[0067]   The example illustrated corresponds to the first embodiment. The movement of the object is a pseudo-periodic translation. More precisely, a finger placed within the field of view of the detectors D1 and D2 is moved in a back and forth movement (noted R in figure 1)

[0068]   Figure 6 shows the detector's output signal in response to the movement of the finger. In this example, the radiation source was an infrared LED oriented toward the finger and modulated by a sinus at a frequency of 40Hz.

[0069]   In each embodiment, it is thus proposed a method and contactless device for measuring the angular position of an object with an acuity much better than the one imposed by the inter-receptor angle $\Delta\varphi$.

Claims

1. Method for measuring the relative angular position of an object (E) and an angular position measuring device (10) comprising at least a first and a second transducers (D1, D2) delimiting respectively a first and a second reception fields, the first and second reception fields overlapping in an area defined as the field of view (FOV) of the device (10), the method comprising the following steps:

    a) carrying out an amplitude modulation of the signals (Ph1, Ph2) delivered by the first and the second transducers (D1, D2); and
    b) calculating an output signal (A) starting from the amplitude modulated signals (Ph1, Ph2) delivered by the first and the second transducers (D1, D2) as a function of said relative angular position,
    characterized in that step a) is done by receiving radiation (N), whose intensity is modulated in time at a known frequency (F), from said object (E) with said transducers (D1, D2) within the field of view (FOV).

2. Method according to claim 1, further comprising the step of illuminating said object (E) with a radiation (M) such that said reception of said radiation (N) occurs by reflection from said object (E) into said field of view (FOV).

3. Method according to claim 1, further comprising the step of illuminating the object with a plurality of radiations (M1, M2, M3) having the same wavelength and synchronised such that said reception of said radiation (N) occurs by reflection from said object (E) of the into said field of view (FOV).

4. Method according to claim 2 or 3, wherein said object (E) is one or several radiation sources emitting said radiation (N).

5. Method according to any one of claims 1 to 4, wherein the output signal (A) is the difference-to-sum ratio of the amplitudes of the temporally filtered signals delivered by the first and the second transducers (D1, D2).

6. Method according to any one of claims 1 to 4, wherein the output signal (A) is proportional to the difference between the logarithm of the absolute value of the temporally filtered signal delivered by the first transducer (D1) and the logarithm of the absolute value of the temporally filtered signal delivered by the second transducer (D2).

7. Method according to any one of claims 1 to 6, further comprising a step of demodulation of the signals (Ph1, Ph2) delivered by the first and the second transducer (D1, D2) before the step of calculating the output signal (A), the output signal (A) being calculated starting from the demodulated signals.

8. Method according to claim 7, wherein the demodulation is an asynchronous demodulation, a synchronous demodulation or an envelope detection of the signals (Ph1, Ph2) delivered by the first and the second transducers (D1, D2).

9. Method according to claim 7 or 8, wherein the demodulation involves a step of filtering the signals (Ph1, Ph2) delivered by the first and the second transducer (D1, D2), said filtering being a selective filtering centered on said known modulation frequency (F), a derivative filtering, or a combination of both a selective filtering on said known modulation frequency (F) and a derivative filtering..

10. Method according to any one of claims 1 to 9, wherein said transducers (D1, D2) are optical sensors, such as photoelectric sensors, and said radiation (M) is optical radiation, such as infrared radiation.

11. Method for measuring the relative angular position of each of a plurality of objects (E1, E2) and an angular position measuring device (12) comprising at least a first and a second transducers (D1, D2) delimiting respectively a first and a second reception fields, the first and second reception fields overlapping in an area defined as the field of view (FOV) of the device (12), wherein the method according to any one of claims 1 to 10 is carried out for each of said objects (E1, E2), each object (E1, E2) being associated with a specific radiation having its own unique modulation frequency.

12. Device (10) for measuring the relative angular position of an object (E) and said device (10), the device (10) comprising:

    - at least a first and a second transducers (D1, D2) delimiting respectively a first and a second reception fields, the first and second reception fields overlapping in an area defined as the field of view (FOV) of the device (10); and

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- a detection circuit (20) comprising a means (24) for calculating an output signal (A) starting from the signals (Ph1, Ph2) delivered by the first and the second transducers (D1, D2) as a function of said relative angular position,

characterized in that the device (10) further comprises a radiation source (30) adapted to emit radiation (M), whose intensity is modulated in time at a known frequency (F), towards said object (E) such that said radiation (M) is reflected from said object (E) into said field of view (FOV).

13. Device according to claims 11 or 12, wherein said transducers (D1, D2) are optical sensors, such as photoelectric sensors, and said radiation source (30) is an optical radiation source, such as an infrared source.

14. Device according to claim 12 or 13, further comprising a lens (L) having a lens center (O), the first and second transducers (D1, D2) being placed substantially in the image focal plane of the lens (L) and the average directions of observation of the first and second transducers (D1, D2) corresponding substantially to two lines linking the centers of the first and second transducer and the lens center (O) of the lens (L).

15. Device according to any one of claims 12 to 14, wherein the detection circuit (20) comprises a demodulator (26) for demodulating the signals (Ph1, Ph2) delivered by the first and the second transducers (D1, D2).

16. Method according to any one of claims 1 to 11 or device according to any one of claims 12 to 15, wherein each transducer (D1, D2) has an angular sensitivity function with a spatial shape that can be approximated by a spatial Gaussian shape **characterized by** a variance (σ^2), the shape being **characterized by** an angle at half-width ($\Delta\rho$) proportional to the square root of the variance (σ^2) of the Gaussian shape.

17. Set of devices comprising at least one lens, at least three transducers and a plurality of detection circuits, each pair of two consecutive transducers being placed close to the focal plane of one of the at least one lens and connected to one of the plurality of detection circuits, wherein at least one device is a device according to any one of claims 12 to 16 and includes one of the at least one lens, and wherein each lens of the at least one lens and each transducer are arranged substantially on a spherical, cylindrical or curved surface surrounding at least one local common centre, the at least one local common centre constituting the centre of field of view (FOVt) which is the sum over all fields of view (FOVi) of each of the devices taken together.
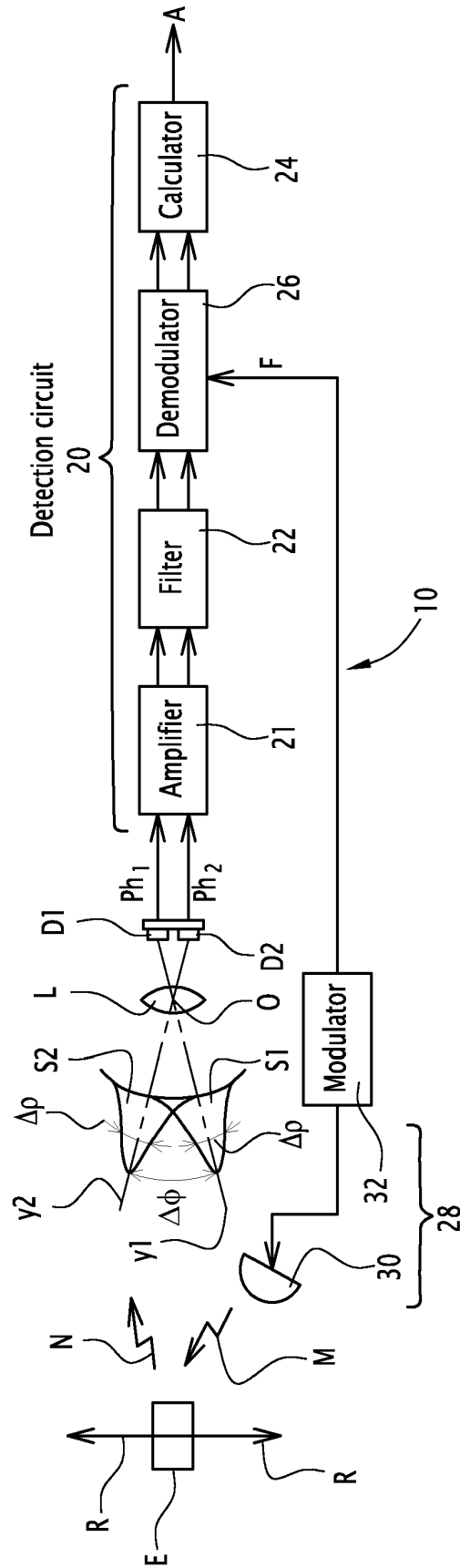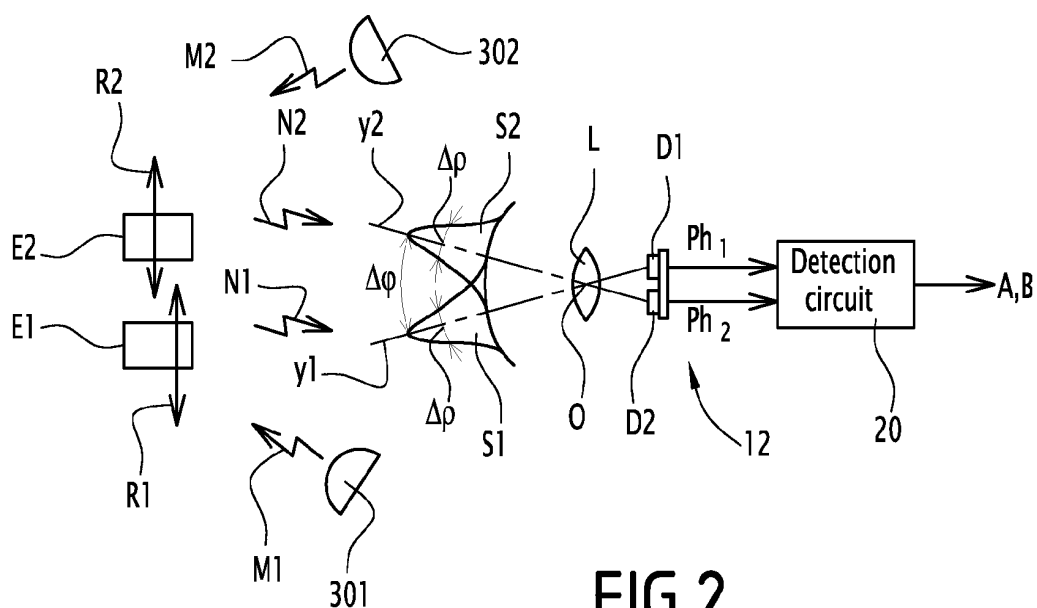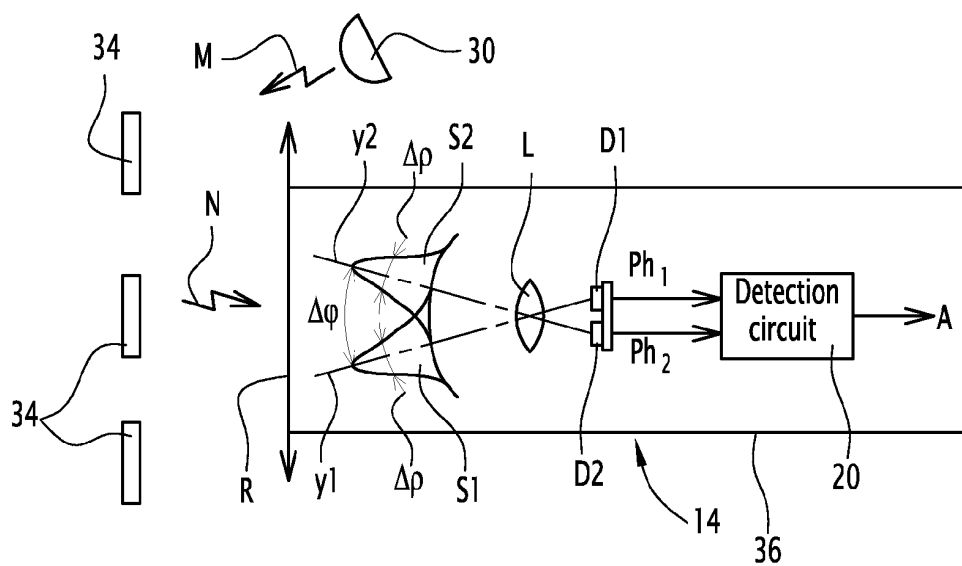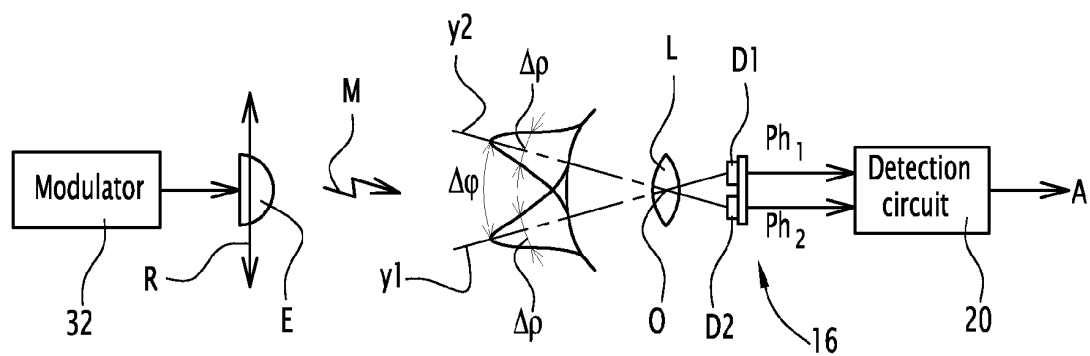
FIG.1

FIG.2

FIG.3

FIG.4

FIG.5

FIG.6
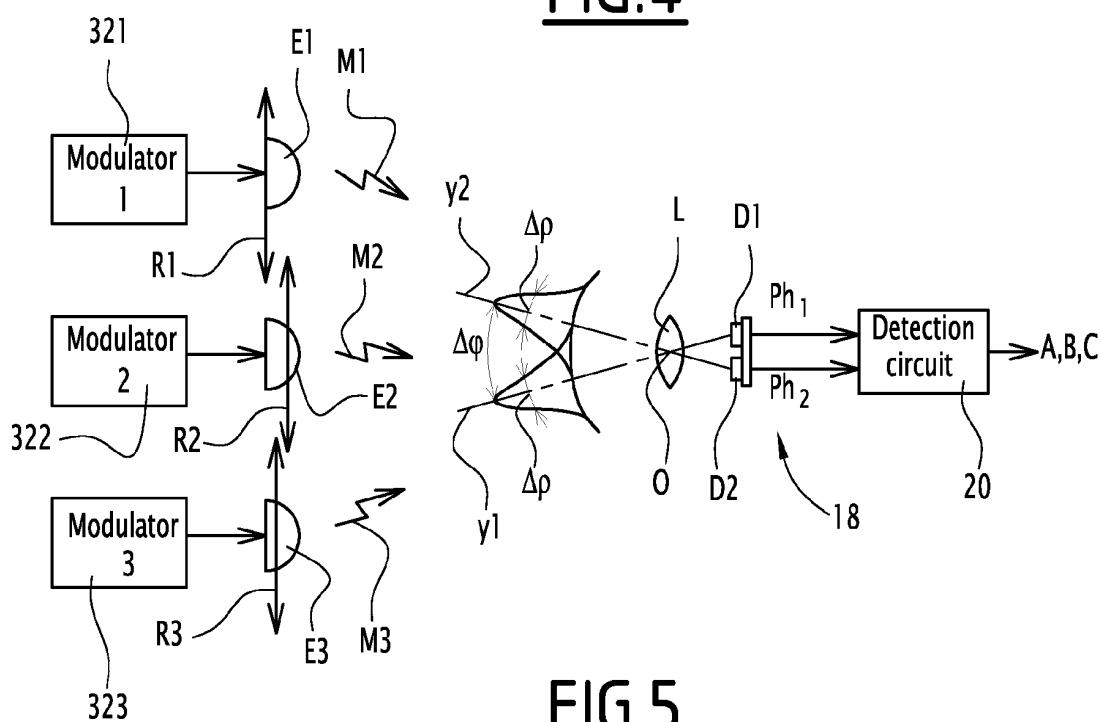
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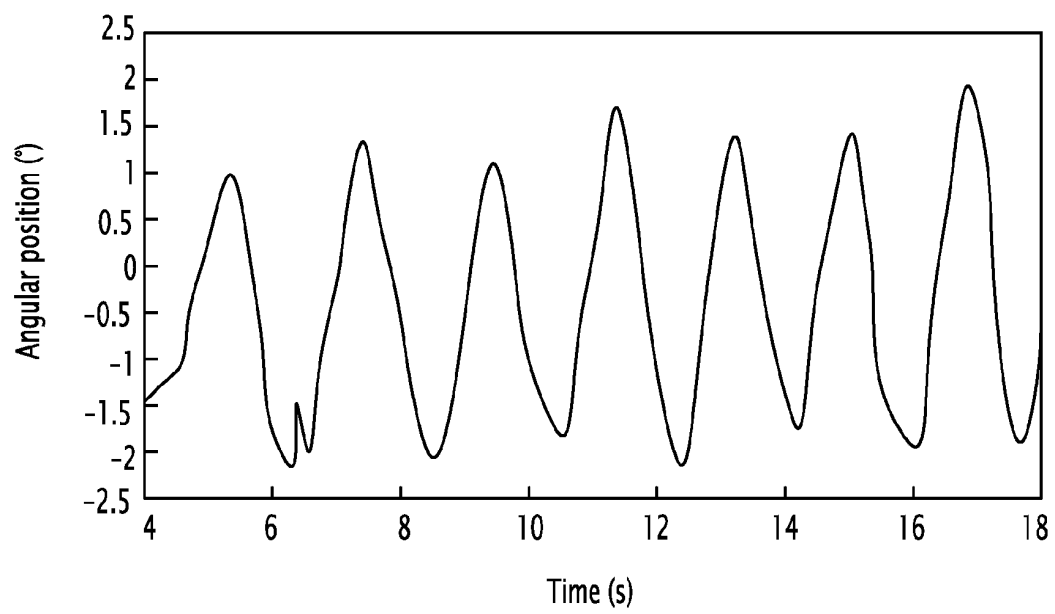European
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EUROPEAN SEARCH REPORT

Application Number

EP 12 30 5554

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 5 216 486 A (SULLEROT DAVID [FR] ET AL) 1 June 1993 (1993-06-01)	1,10, 12-14	INV. G01B11/02
Y	* column 3, line 3 - column 4, line 49; claims 1,5; figures 1,2 *	1-17	
X	US 6 031 612 A (SHIRLEY LYLE [US]) 29 February 2000 (2000-02-29)	1-3,10, 12-14	
Y	* column 5, line 48 - line 64; figure 1 *	1-17	
Y,D	EP 2 341 312 A1 (UNIV AIX MARSEILLE II [FR]; CENTRE NAT RECH SCIENT [FR]) 6 July 2011 (2011-07-06) * the whole document *	1-17	

TECHNICAL FIELDS
SEARCHED   (IPC)

G01B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	29 August 2012	Grand, Jean-Yves

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 12 30 5554

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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29-08-2012

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5216486	A	01-06-1993	AT	117073 T	15-01-1995
			CA	2058044 A1	22-06-1992
			DE	69106683 D1	23-02-1995
			DE	69106683 T2	11-05-1995
			EP	0493213 A1	01-07-1992
			FI	915963 A	22-06-1992
			FR	2670883 A1	26-06-1992
			JP	4276504 A	01-10-1992
			US	5216486 A	01-06-1993
US 6031612	A	29-02-2000	US	6031612 A	29-02-2000
			WO	9963304 A1	09-12-1999
EP 2341312	A1	06-07-2011	EP	2341312 A1	06-07-2011
			WO	2011073079 A1	23-06-2011

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- EP 2341312 A1 **[0003] [0005] [0030]**