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(54) **LUMINANCE SMOOTHENING SYSTEM AND LUMINANCE CONTROLLER THEREOF**

(57) A luminance smoothening system includes an illuminating unit, an ambient luminance sensor and a luminance controller. The ambient luminance sensor detects an analog ambient luminance. The luminance controller includes an A/D converter and an adaptive luminance adjusting module. The A/D converter is electrically coupled to the ambient luminance sensor. The A/D converter receives the analog ambient luminance signal. The A/D converter transforms the analog ambient luminance signal to a digital ambient luminance signal. The adaptive

luminance adjusting module is electrically coupled to the illuminating unit. The adaptive luminance adjusting module generates an output luminance control signal at a current stage based on a first adjusted ratio of the digital ambient luminance signal at the current stage and a second adjusted ratio of the output luminance control signal at a previous stage. The adaptive luminance adjusting module controls the illuminating unit using the output luminance control signal at the current stage.

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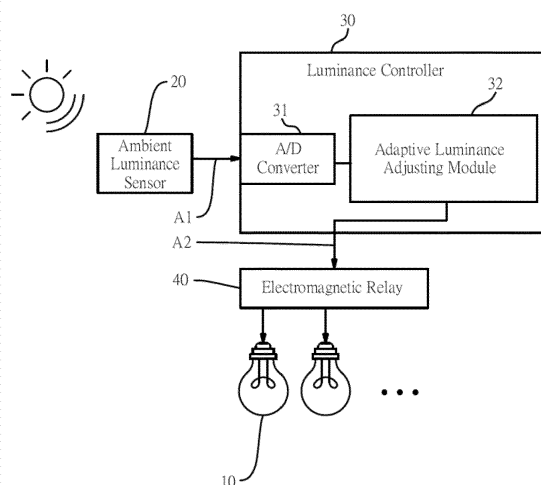


FIG. 1

Description

TECHNICAL FIELD

[0001] The present invention relates to a luminance smoothening system and a luminance controller applied on the luminance smoothening system, and more particularly to a luminance smoothening system capable of smoothly adjusting an illuminating unit's luminance in a smooth manner and a luminance controller that aids the luminance smoothening system in said capability.

BACKGROUND

[0002] Light adaption refers to human eyes' susceptibility to various degrees of luminance variation. For example, while a person rapidly exits a bright environment and enters a dark one, he/she will loss his/her sights for a short while and then gradually restore his/her vision, where such phenomenon is called as dark adaptation. On the contrary, when a person suddenly leaves a dark place and runs into a bright one, he/she will see nothing more than lights and then restore his/her vision on objects or environments for at least a few seconds, where such phenomenon is called as light adaptation.

[0003] Dark adaptation encompasses two basic processes, including a first variation of pupil's size and a second variation of retina's photosensitive chemical materials. From bright to dark, the pupil's diameter expands substantially from 2 millimeters to 8 millimeters, such that light that enter human's naked eyes amplifies by ten to twenty folds. Light adaptation subsides fast, and usually ends within tens of seconds. Under the sudden movement from a dark place to another bright one, the naked eyes are triggered by a strong light variation. In turn, a retina's cone cells responds immediately, such that in the beginning of the light adaptation, just a few cone cells are timely triggered, and the naked eyes become highly susceptible to light stimulation and unable to see clear contour of objects in his/her sight.

[0004] A strong luminance variation can also be created by switching on an illuminating unit, such as a LED (Light-Emitting Diode) unit. Specifically, a LED unit can emit an extremely high density of luminance during a significantly short period and then reach its maximal luminance rapidly. As human eyes respond to such extreme luminance change, his/her pupils may suffer un-restorable damage because of rapid and highly frequent expansions and contractions.

SUMMARY

[0005] The present disclosure aims at disclosing a luminance controller that includes an A/D (Analog-to-Digital) converter and an adaptive luminance adjusting module. The A/D converter receives an analog ambient luminance signal. Also, the A/D converter transforms the analog ambient luminance signal to a digital ambient lumi-

nance signal. The adaptive luminance adjusting module generates an output luminance control signal at a current stage based on a first adjusted ratio of the digital ambient luminance signal at the current stage and a second adjusted ratio of the output luminance control signal at a previous stage. In addition, the adaptive luminance adjusting module controls the illuminating unit using the output luminance control signal at the current stage.

[0006] In one example, the adaptive luminance adjusting module is further configured to generate the output luminance control signal at the current stage using the following formula:

$$Y[n]=f\{X[n]\times\alpha+(1-\alpha)\times Y[n-1]\};$$

n refers to the current stage and is a nonnegative integer, Y[n] refers to the output luminance control signal at the current stage, Y[n-1] refers to the output luminance control signal at the previous stage, X[n] refers to the digital ambient luminance signal at the current stage, α refers to the first ratio, and f{ } refers to a rounding function that rounds its input a designated decimal place.

[0007] In one example, the rounding function includes a rounding down function.

[0008] In one example, the rounding function includes a rounding up function.

[0009] In one example, the rounding function includes a rounding off function.

[0010] In one example, the rounding function includes a rounding towards zero function.

[0011] In one example, the rounding function includes a rounding away from zero function.

[0012] In one example, the luminance controller includes at least one microprocessor, a digital signal processor, a programmable controller, an application specific integrated circuit, and a radio-frequency system-on-chip.

[0013] The disclosure also discloses a luminance smoothening system that includes an illuminating unit, an ambient luminance sensor and a luminance controller. The ambient luminance sensor detects an analog ambient luminance of the luminance smoothening system. The luminance controller includes an A/D converter and an adaptive luminance adjusting module. The A/D converter is electrically coupled to the ambient luminance sensor. Also, the A/D converter receives the analog ambient luminance signal from the ambient luminance sensor. In addition, the A/D converter transforms the analog ambient luminance signal to a digital ambient luminance signal. The adaptive luminance adjusting module is electrically coupled to the illuminating unit. Moreover, the adaptive luminance adjusting module generates an output luminance control signal at a current stage based on a first adjusted ratio of the digital ambient luminance signal at the current stage and a second adjusted ratio of the output luminance control signal at a previous stage. Besides, the adaptive luminance adjusting module con-

trols the illuminating unit using the output luminance control signal at the current stage.

[0014] In one example, the adaptive luminance adjusting module generates the output luminance control signal at the current stage using the following formula:

$$Y[n]=f\{X[n]\times\alpha+(1-\alpha)\times Y[n-1]\};$$

n refers to the current stage and is a nonnegative integer, Y[n] refers to the output luminance control signal at the current stage, Y[n-1] refers to the output luminance control signal at the previous stage, X[n] refers to the digital ambient luminance signal at the current stage, α refers to the first ratio, and f{ } refers to a rounding function that rounds its input a designated decimal place.

[0015] In one example, the rounding function includes a rounding down function.

[0016] In one example, the rounding function includes a rounding up function.

[0017] In one example, the rounding function includes a rounding off function.

[0018] In one example, the rounding function includes a rounding towards zero function.

[0019] In one example, the rounding function includes a rounding away from zero function.

[0020] In one example, the luminance smoothening system additionally includes an electromagnetic relay. And the electromagnetic relay is electrically coupled to the illuminating unit and the luminance controller. Also, the electromagnetic relay determines an operating power for driving the illuminating unit according to the output luminance control signal at the current stage.

[0021] In one example, the luminance controller includes at least one microprocessor, a digital signal processor, a programmable controller, an application specific integrated circuit, and a radio-frequency system-on-chip.

[0022] In one example, the ambient luminance sensor includes at least one of a CMOS (Complementary Metal-Oxide Semiconductor) image sensor, a radiation heat sensor, a CCD (Charge-Coupled Device), a photoelectric diode, a photo resistor, and a photo transistor.

[0023] In one example, the illuminating unit includes a LED (Light-Emitting Diode) element.

[0024] In one example, the LED element includes at least one LED ceiling light, a LED downlight, a LED bulb, a LED lamp, a LED panel light, a LED spotlight, and a LED street lamp.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

FIG. 1 illustrates a schematic diagram of a luminance smoothening system according to one embodiment of the present disclosure.

FIG. 2 illustrates an exemplary chart of the adaptive

luminance adjusting module of Fig. 1's rounding functions.

DESCRIPTION OF THE EMBODIMENTS

[0026] For smoothening an illuminating unit's rapid luminance variation that may damage human's pupils, the present disclosure discloses a luminance smoothening system and its luminance controller. Specifically, the luminance controller is capable of referencing both an output luminance at a previous stage (e.g. an immediate-previous stage) and a currently-detected ambient luminance for dynamically adjusting its output luminance at a current stage. In this way, the illuminating unit's output luminance can be smoothly increasing after being activated. In other words, human pupils can be substantially prevented from the illuminating unit's abruptly-increased luminance.

[0027] Please refer to FIG. 1, which illustrates a schematic diagram of a luminance smoothening system 100 according to one embodiment of the present disclosure. The luminance smoothening system 100 includes at least one illuminating unit 10, an ambient luminance sensor 20 and a luminance controller 30, which is just the disclosed luminance controller of the present disclosure.

[0028] In some examples, the at least one illuminating unit 10 is a LED element. Moreover, in some examples, the at least one illuminating unit 10 is implemented using at least one or a combination of a LED ceiling light, a LED downlight, a LED bulb, a LED lamp, a LED panel light, a LED spotlight, and a LED street lamp.

[0029] The ambient luminance sensor 20 detects an analog ambient luminance signal (i.e., an analog signal) of the luminance smoothening system 100. In some examples, the ambient luminance sensor 20 is implemented using at least one or a combination of a CMOS (Complementary Metal-Oxide Semiconductor) image sensor, a radiation heat sensor, a CCD (Charge-Coupled Device), a photoelectric diode, a photo resistor, and a photo transistor.

[0030] The luminance controller 30 includes an A/D converter 31 and an adaptive luminance adjusting module 32. The A/D converter 31 receives the analog ambient luminance signal from the ambient luminance sensor 20. In addition, the A/D converter 31 transforms the analog ambient luminance signal to a digital ambient luminance signal, such that the adaptive luminance adjusting module 32 can perform calculations based on the digital ambient luminance signal.

[0031] The adaptive luminance adjusting module 32 performs a luminance smoothening algorithm to fulfill the abovementioned dynamic adjustment. For performing required calculations, besides using the digital ambient luminance signal as its input, the luminance controller 30 can be implemented using, for example, at least one or any combination of a microprocessor, a digital signal processor, a programmable controller, an application specific integrated circuit, and a RF (radio-frequen-

cy)SoC (System-on-Chip). Moreover, when the luminance controller 30 requires additional memory for storing parameters, lookup tables, or failure records, the luminance controller 30 may additionally include an additional memory unit, which may be implemented using, for example, an EEPROM (Electrically-Erasable Programmable Read-Only Memory).

[0032] In some examples, the adaptive luminance adjusting module 32 smoothly and dynamically adjusts the digital ambient luminance signal, i.e., adjusting the at least one illuminating unit 10's luminance. And the adaptive luminance adjusting module 32 conducts the smooth and dynamic adjustment by generating the output luminance control signal at a current stage using the following formula:

$$Y[n]=f\{X[n]\times\alpha+(1-\alpha)\times Y[n-1]\} \quad (1)$$

[0033] Specifically, n refers to a current stage and is a nonnegative integer. Y[n] refers to the output luminance control signal at the current stage, such that Y[n-1] refers to the output luminance control signal at a previous stage in time (i.e., directly preceding to Y[n]), X[n] refers to the digital ambient luminance signal at the current stage, α refers to a first ratio for X[n], such that 1- α refers to a second ratio for Y[n-1], and f{} refers to a rounding function that rounds its input a designated decimal place.

[0034] In brief, the adaptive luminance adjusting module 32 dynamically determines the illuminating unit 10's output luminance by referencing both an immediately-preceding output luminance signal and a currently-detected ambient luminance, and by modifying both the parameters using different ratios. In this way, the output luminance signal can be adjusted in a way that gradually increases or decreases itself, such that the illuminating unit 10's luminance will not force a person pupil to rapidly expand or shrink, and this person's eyes can be substantially protected.

[0035] Moreover, the adaptive luminance adjusting module 32 additionally rounds the output luminance signal to a desired decimal digit, and it means the luminance controller 30 is capable of freely controlling the output luminance signal's resolution for fine-tuning.

[0036] In some examples, the first ratio α is well pre-determined for controlling the output luminance signal's tendency to gradual increase or decrease. In most examples, the first ratio α 's value is between 0 and 1, such that the second ratio 1- α 's value also ranges between 0 and 1.

[0037] In some examples, the rounding function f{} is a rounding down function. In some examples, there is no designated decimal place, such that the rounding down function f{}'s output is an integer. For example, if the digital outputted luminance's value is 2.9, the rounding down function f{}'s value is 2. In some examples, if there is one designated decimal place, the rounding down func-

tion f{}'s output will be rounded to its first decimal place. For example, if the digital outputted luminance's value is 2.83, the rounding down function f{}'s value is 2.8.

[0038] In some examples, the rounding function f{} is a rounding up function. In some examples, there is no designated decimal place, such that the rounding up function f{}'s output is an integer. For example, if the digital outputted luminance's value is 2.9, the rounding up function f{}'s value is 3. In some examples, if there is one designated decimal place, the rounding up function f{}'s output will be rounded to its first decimal place. For example, if the digital outputted luminance's value is 2.83, the rounding down function f{}'s value is 2.9.

[0039] In some examples, the rounding function f{} is a rounding off function. In some examples, there is no designated decimal place, such that the rounding off function f{}'s output is an integer. For example, if the digital outputted luminance's value is 2.9, the rounding off function f{}'s value is 3. In some examples, if there is one designated decimal place, the rounding off function f{}'s output will be rounded to its first decimal place. For example, if the digital outputted luminance's value is 2.83, the rounding down function f{}'s value is 2.8.

[0040] In some examples, the rounding function f{} is a rounding towards zero function. In some examples, there is no designated decimal place, such that the rounding towards zero function f{}'s output is an integer. For example, if the digital outputted luminance's value is -2.9, the rounding towards zero function f{}'s value is -2. In some examples, if there is one designated decimal place, the rounding towards zero function f{}'s output will be rounded to its first decimal place. For example, if the digital outputted luminance's value is -2.87, the rounding towards zero function f{}'s value is -2.8.

[0041] In some examples, the rounding function f{} is a rounding away from zero function. In some examples, there is no designated decimal place, such that the rounding away from zero function f{}'s output is an integer. For example, if the digital outputted luminance's value is -2.9, the rounding away from zero function f{}'s value is -3. In some examples, if there is one designated decimal place, the rounding away from zero function f{}'s output will be rounded to its first decimal place. For example, if the digital outputted luminance's value is -2.87, the rounding away from zero function f{}'s value is -2.9.

[0042] In some other examples, the adaptive luminance adjusting module may choose different designated decimal places for the output luminance signal's resolution. And embodiments formed by merely choosing different values of decimal places should also be considered as the present disclosure's embodiments.

[0043] Please refer to FIG. 2, which illustrates an exemplary chart of the adaptive luminance adjusting module 32's rounding functions. Specifically, the exemplary chart's assumption includes: (1) the rounding function f{}'s designated decimal place is 0 (i.e., its output is an integer); and (2) the digital output luminance signal's values are {-3.5, -2.9, -1.1, 1.1, 2.9, 3.5}. In this way, first,

when the rounding function $f\{\}$ is a rounding down function (labeled as "FLOOR"), its output values are $\{-4, -3, -2, 1, 2, 3\}$. Second, when the rounding function $f\{\}$ is a rounding up function (labeled as "CEIL"), its output values are $\{-3, -2, -1, 2, 3, 4\}$. Third, when the rounding function $f\{\}$ is a rounding off function (labeled as "ROUND"), its output values are $\{-4, -3, -1, 1, 3, 4\}$. Fourth, when the rounding function $f\{\}$ is a rounding towards zero function (labeled as "INT"), its output values are $\{-3, -2, -1, 1, 2, 3\}$. Fifth, when the rounding function $f\{\}$ is a rounding away from zero function (labeled as "INT+SIGN"), its output values are $\{-4, -3, -2, 2, 3, 4\}$.

[0044] In some examples, the luminance smoothening system 100 additionally includes an electromagnetic relay 40, which is electrically coupled to the illuminating unit 10 and the luminance controller 30. Also, the electromagnetic relay 40 determines an operating power for driving the illuminating unit 10 according to the luminance controller 30's output luminance control signal at the current stage (i.e., dynamically determination).

[0045] In summary, the adaptative luminance adjusting module 32 dynamically adjusts its digital output luminance signal based on its ambient luminance and its preceding output luminance, such that the adaptative luminance adjusting module 32 generates its output luminance signal in a dynamic and step-up/step-down manner. In this way, the illuminating unit 10's luminance can also be smoothly stepping-up or stepping-down and substantially prevent human pupils from abrupt expansion or shrinking, i.e., vision damages.

Claims

1. A luminance controller, comprising:

an analog-to-digital (A/D) converter, configured to receive an analog ambient luminance signal, and configured to transform the analog ambient luminance signal to a digital ambient luminance signal; and
an adaptive luminance adjusting module, configured to generate an output luminance control signal at a current stage based on a first adjusted ratio of the digital ambient luminance signal at the current stage and a second adjusted ratio of the output luminance control signal at a previous stage, and configured to control the illuminating unit using the output luminance control signal at the current stage.

2. The luminance controller of claim 1, **characterized in that**, the adaptive luminance adjusting module is further configured to generate the output luminance control signal at the current stage using the following formula:

$$Y[n]=f\{X[n]\times\alpha+(1-\alpha)\times Y[n-1]\}$$

wherein n refers to the current stage and is a non-negative integer, $Y[n]$ refers to the output luminance control signal at the current stage, $Y[n-1]$ refers to the output luminance control signal at the previous stage, $X[n]$ refers to the digital ambient luminance signal at the current stage, α refers to the first ratio that ranges between 0 and 1, and $f\{\}$ refers to a rounding function that rounds its input to a designated decimal place.

3. The luminance controller of claim 2, **characterized in that**, the rounding function comprises a rounding down function.

4. The luminance controller of claim 2, **characterized in that**, the rounding function comprises a rounding up function.

5. The luminance controller of claim 2, **characterized in that**, the rounding function comprises a rounding off function.

6. The luminance controller of claim 2, **characterized in that**, the rounding function comprises a rounding towards zero function.

7. The luminance controller of claim 2, **characterized in that**, the rounding function comprises a rounding away from zero function.

8. The luminance controller of claim 1, **characterized in that**, the luminance controller comprises at least one microprocessor, a digital signal processor, a programmable controller, an application specific integrated circuit, and a radio-frequency system-on-chip.

9. A luminance smoothening system, comprising:

an illuminating unit;
an ambient luminance sensor, configured to detect an analog ambient luminance signal of the luminance smoothening system; and
a luminance controller, comprising:

an A/D converter, electrically coupled to the ambient luminance sensor, configured to receive the analog ambient luminance signal from the ambient luminance sensor, and configured to transform the analog ambient luminance signal to a digital ambient luminance signal; and
an adaptive luminance adjusting module, electrically coupled to the illuminating unit,

configured to generate an output luminance control signal at a current stage based on a first adjusted ratio of the digital ambient luminance signal at the current stage and a second adjusted ratio of the output luminance control signal at a previous stage, and configured to control the illuminating unit using the output luminance control signal at the current stage.

10. The luminance smoothening system of claim 9, **characterized in that**, the adaptive luminance adjusting module is further configured to generate the output luminance control signal at the current stage using the following formula:

$$Y[n]=f\{X[n]\times\alpha+(1-\alpha)\times Y[n-1]\};$$

wherein n refers to the current stage and is a non-negative integer, Y[n] refers to the output luminance control signal at the current stage, Y[n-1] refers to the output luminance control signal at the previous stage, X[n] refers to the digital ambient luminance signal at the current stage, α refers to the first ratio that ranges between 0 and 1, and f{} refers to a rounding function that rounds its input to a designated decimal place.

11. The luminance smoothening system of claim 10, **characterized in that**, the rounding function comprises a rounding down function.
12. The luminance smoothening system of claim 10, **characterized in that**, the rounding function comprises a rounding up function.
13. The luminance smoothening system of claim 10, **characterized in that**, the rounding function comprises a rounding off function.
14. The luminance smoothening system of claim 10, **characterized in that**, the rounding function comprises a rounding towards zero function.
15. The luminance smoothening system of claim 10, **characterized in that**, the rounding function comprises a rounding away from zero function.
16. The luminance smoothening system of claim 9, further comprising:
an electromagnetic relay, electrically coupled to the illuminating unit and the luminance controller and configured to determine an operating power for driving the illuminating unit according to the output luminance control signal at the current stage.

17. The luminance smoothening system of claim 9, **characterized in that**, the luminance controller comprises at least one microprocessor, a digital signal processor, a programmable controller, an application specific integrated circuit, and a radio-frequency system-on-chip.

18. The luminance smoothening system of claim 9, **characterized in that**, the ambient luminance sensor comprises at least one of a CMOS image sensor, a radiation heat sensor, a CCD, a photoelectric diode, a photo resistor, and a photo transistor.

19. The luminance smoothening system of claim 9, **characterized in that**, the illuminating unit comprises a LED element.

20. The luminance smoothening system of claim 19, **characterized in that**, the LED element comprises at least one LED ceiling light, a LED downlight, a LED bulb, a LED lamp, a LED panel light, a LED spotlight, and a LED street lamp.

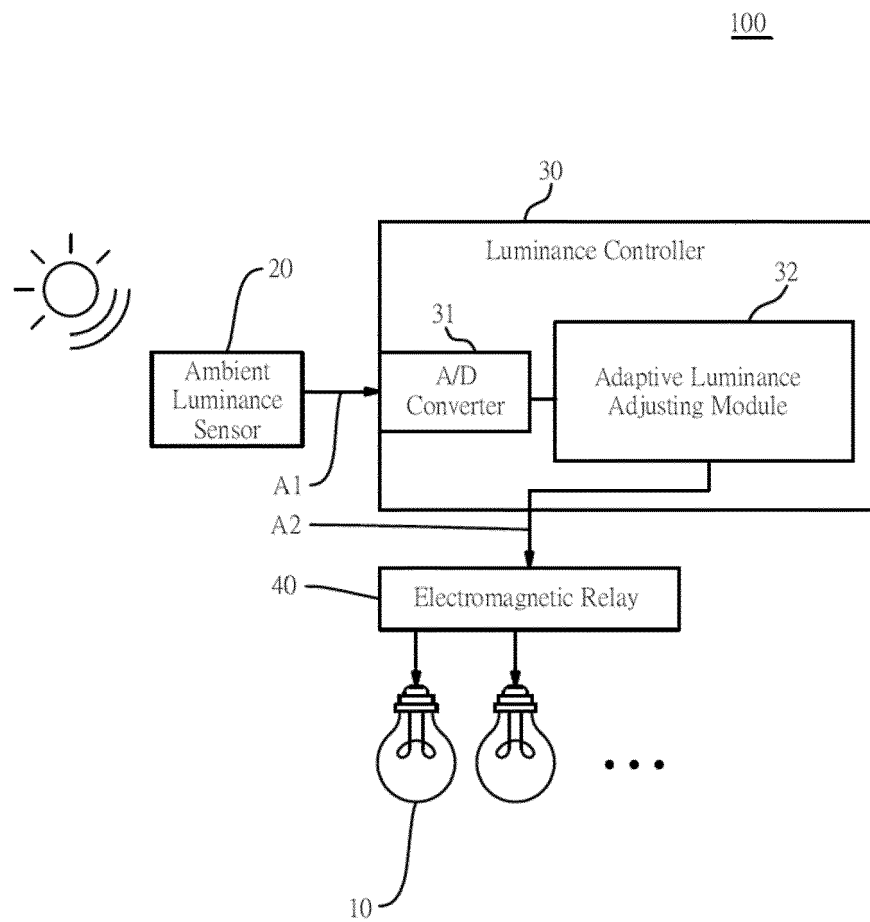


FIG. 1

Rounding Functions						
	-3.5	-2.9	-1.1	1.1	2.9	3.5
FLOOR	-4	-3	-2	1	2	3
CEIL	-3	-2	-1	2	3	4
ROUND	-4	-3	-1	1	3	4
INT	-3	-2	-1	1	2	3
INT+SIGN	-4	-3	-2	2	3	4

FIG. 2



EUROPEAN SEARCH REPORT

Application Number
EP 20 18 9838

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 25 November 2020	Examiner Garavini, Elisa
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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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