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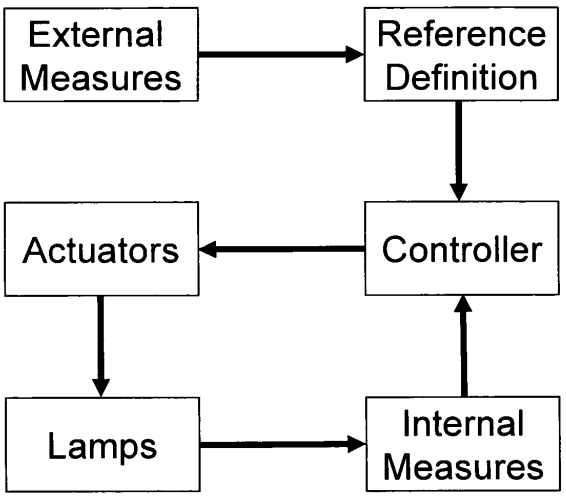
(54) A system and a process for controlling the light intensity in a tunnel

(57) A system and a method for controlling the light intensity in a road tunnel or in any other ambient with similar characteristics based on the dense measurement of internal illumination-related quantities and other physical parameters, such that the illumination converges to a dynamically computed reference set point defined on the basis of law, regulations, energy consumption restrictions, users' comfort or any other criterion or combination thereof that is deemed fit for the definition of said reference set point; said reference set point can be based on any number of measures (as well as none) taken outside the illuminated ambient; said measurement points inside the illuminated ambient are dense in the sense that they allow the characterization of any meaningful portion of the illuminated ambient; said measurement points can be in number less, equal or more than the number of illumination devices.

Figur 1



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Description

[0001] The present invention relates to a system and process for controlling the light intensity in a tunnel.

[0002] The state of the art on road tunnels and underpass illumination systems is bound to open-loop control of the illumination level based on a single parameter (time of day or external illumination level or veil luminance). Ambient characteristics are taken into account only statically based in the project and dimensioning of the plant. Samples of these systems are: Reverberi SDL TC veil luminance sensor [1], Techno Team Video Photometer [2] and Thorn North Star Lighting [3].

[0003] International and national regulations for the illumination of road, tunnels, underpasses, and other similar infrastructures impose strict limits in terms of the luminance and contrast perception for drivers and users. Applicability goes beyond tunnels and roads and can be extended to any situation where the security, safety, or simply comfort of use, require well-defined luminance levels. Energy consumption may or may not be a primary concern, but the strict adherence to rules (in contrast to over-dimensioning) of the proposed system guarantees energy consumption minimization.

[0004] The inventive illumination system is composed of six main functional blocks as illustrated in Fig. 1. The core and innovation of the system are in Internal Measures, Controller, and in part in External Measures.

[0005] The External Measures block includes a set, possibly with a single component, of measurements performed outside the area of controlled illumination, which are related to the specific ambient and scope of the illumination. Such measures can include luminance measurement, traffic measures (for roads), weather and physical environment conditions, etc. Based on these measurements the Reference Definition block computes a *reference set point* (which is indeed a complex curve function of time and space) for the illumination.

[0006] The Lamps block is a set of illumination devices. It is possibly heterogeneous and can include natural illumination sources (such as light wells collecting and regulating the flow of sunlight) and artificial illumination sources such as incandescence lamps, LEDs, and in general any light-emitting device. The Actuators block includes means for regulating the light flow of the devices in the Lamps block. Actuation techniques may operate on single illumination devices or groups thereof. Regulation techniques include, but are not limited to: 1) switching on and off illumination devices; 2) changing the driving voltage or current; 3) changing the duty-cycle of current; 4) screening the light source.

[0007] The Internal Measures block is a complex ensemble of functions which include: 1) measuring one or more of the following quantities: luminance, illumination, temperature, infrared radiation, ultraviolet radiation, reflectivity of walls, floor and ceiling; 2) collecting and transmitting the above measures to one or more collection points called *gateways;* 3) elaborating and normalizing such information and measures; 4) communicating periodically or asynchronously the measures and information to the Controller.

[0008] The Controller block is a hardware device with computational capabilities that, based on a suitable algorithm, can regulate the actuators such that the actual illumination parameters as measured by the Internal Measures block do not differ from the said reference set point by more than a predefined quantity. The algorithms used by the Controller may include robust and optimal control theory techniques, heuristic adaptations and neural networks or other artificial intelligence techniques suitable to minimize the residual error between the reference set point and the actual measures.

[0009] The system described herein contains several innovations, which can be encompassed in a single invention patent, or split in different patents to provide more protection to IP and more strength to IPRs.

Innovations and inventions

[0010]

1) The concept of gathering external measures of different kinds, as discussed above with respect to the External Measures block, is an improvement on the state of the art, which typically relies on a single kind of measurement. Present day systems for road tunnels use a camera-based sensor to identify the screen luminance; in other applications the illumination in some other key point is measured. Other systems simply use the time of day without any measurement. Our system can use single as well as multiple measures, enabling a computation of the reference set point based upon multiple parameters. Additional measures can be, but are not limited to:

a) presence of traffic;
b) traffic speed and/or density;
c) hazardous conditions like stalling traffic into a tunnel or ongoing security activities in other environments;
d) modified ambient conditions that alters the reaction of drivers (e.g., snow, rain, fog).

2) The dynamic setting of the reference set point, either done with a continuous algorithm or with a tabular function. In state-of-the-art systems the set point is not a reference, rather a working consequence of the actuators settings, which are computed off-line at design time.

3) The fine-grained control of illumination devices both in light level and in space, with the ability of compensating illumination in one point by properly regulating adjacent lamps.

4) The closed loop control of illumination based on

a dense set of measures internal to the controlled system, which can control the entire and can drive it to the reference set point with a controllable error.

Claims

1. A system for controlling the light intensity in a road tunnel or in any other ambient with similar characteristics based on the dense measurement of internal illumination-related quantities and other physical parameters, such that the illumination converges to a dynamically computed reference set point defined on the basis of law, regulations, energy consumption restrictions, users' comfort or any other criterion or combination thereof that is deemed fit for the definition of said reference set point; said reference set point can be based on any number of measures (as well as none) taken outside the illuminated ambient; said measurement points inside the illuminated ambient are dense in the sense that they allow the characterization of any meaningful portion of the illuminated ambient; said measurement points can be in number less, equal or more than the number of illumination devices.

2. A system according to claim 1, wherein the internal measures are collected with a Wireless Sensor Network, i.e., a system of sensing and communicating devices which are not connected by communication wires, but communicate through radio, infrared, or any other suitable means not based on wires, hereby including such devices which are powered by an external source, internal batteries, or ambient (solar, wind, vibrations, thermal, chemical, nuclear, etc.) energy collection systems, including, but not limiting to, such system that accumulate the collected energy in a battery or ultra-capacitor.

3. A system according to claim 1 wherein the controller is implemented though one or more PLCs.

4. A system according to claim 1 wherein the controller is implemented via a general computing device or system, including a distributed implementation on multiple computers.

5. A system according to claim 1, wherein the controller is implemented through a distributed algorithm running on embedded devices, including also a) the case where the controller is implemented directly in the WSN; and b) the case where the WSN is used also to drive the actuators of the lamps.

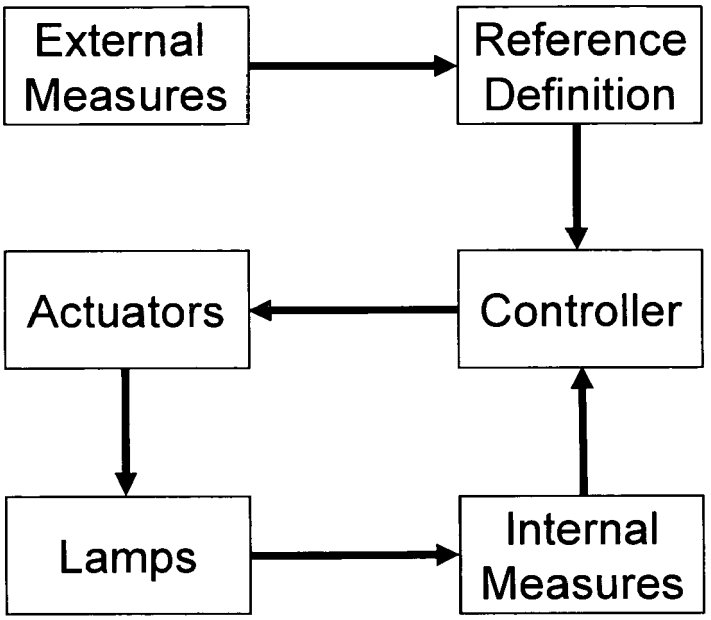
6. A system according to claim 5 wherein sensors and actuators are integrated in one device, including the case of co-location with illumination devices.

7. A system according to claim 1 wherein the measures are illumination measures taken on selected points of the ambient and where the transformation to the Reference Set Point is done via theoretical computation.

8. A system according to claim 1 wherein the measures are luminance measures.

9. A method for controlling the light intensity in a road tunnel or in any other ambient with similar characteristics based on the dense measurement of internal illumination-related quantities and other physical parameters, such that the illumination converges to a dynamically computed reference set point defined on the basis of law, regulations, energy consumption restrictions, users' comfort or any other criterion or combination thereof that is deemed fit for the definition of said reference set point; said reference set point can be based on any number of measures (as well as none) taken outside the illuminated ambient; said measurement points inside the illuminated ambient are dense in the sense that they allow the characterization of any meaningful portion of the illuminated ambient; said measurement points can be in number less, equal or more than the number of illumination devices.

Figur 1


External Measures
Reference Definition
Actuators
Controller
Lamps
Internal Measures

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EUROPEAN SEARCH REPORT

Application Number
EP 09 42 5078

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 2004/160199 A1 (MORGAN FREDERICK M [US] ET AL) 19 August 2004 (2004-08-19) * abstract * * paragraph [0027] * * paragraphs [0172], [0174], [0179], [0181]; figure 1 * * paragraph [0465]; figure 75 *	1-9	INV. G05D25/02
X	GB 2 345 998 A (MEW RAYMOND [GB]; MEW JEANETTE [GB]) 26 July 2000 (2000-07-26) * abstract * * page 7, line 21 - page 8, line 30; figure 1 *	1-9	
X	FR 2 490 363 A (ATB AG TECH BELEUCHTUNG [CH]) 19 March 1982 (1982-03-19) * abstract * * page 1, line 35 - page 2, line 21 * * page 4, line 27 - line 35; figures A,B *	1	

TECHNICAL FIELDS SEARCHED (IPC)

G05D
H05B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 July 2009	Helot, Henri

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 09 42 5078

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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21-07-2009

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