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(54) Title: ESTIMATING LIGHT SENSOR OUTPUT DRIFT

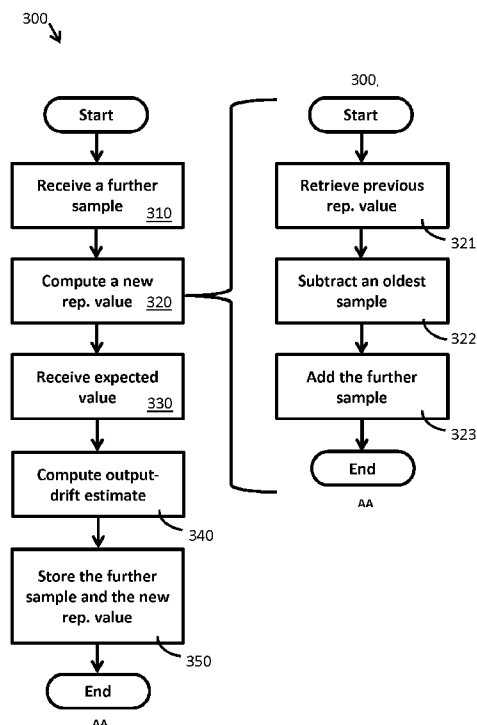


Figure 3

(57) Abstract: An output-drift estimation method (300) for a light sensor output, comprising: obtaining (320) a value representative of a plurality of samples of the light sensor output, wherein all of the samples were sampled over at least one period of 365 consecutive days; determining a difference between the received value and an expected value; and computing (340) an output-drift estimate based on the determined difference. Thus a convenient method of estimating the drift of a light sensor output, which can be used to adaptively calibrate the light sensor output.

**Declarations under Rule 4.17:**

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
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- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

Estimating light sensor output drift

TECHNICAL FIELD

The invention relates generally to light sensors, more particularly to output-drift estimation for light sensor outputs, and to calibrating light sensor outputs.

5 BACKGROUND

Light sensors degrade over their lifetimes, causing their output signals to ‘drift’. A light sensor’s output signal will eventually drift to such an extent that recalibration or replacement is required. This is particularly relevant to outdoor light sensors, e.g. light sensors connected to streetlights. Such sensors are exposed to the natural environment and so
10 tend to become covered with dirt etc., accelerating their degradation and so the drift of their output signals.

Manual recalibration to evaluate and correct the output drift is inconvenient. It may be particularly inconvenient, and expensive, for outdoor light sensors where gaining access in order to carry out the recalibration is inconvenient. Oftentimes the light sensors
15 will be replaced, not recalibrated, thereby shortening the lifetimes of outdoor light sensors. Japanese patent application no. JP2009257813, for example, discloses a predictive method of compensating for output drift in a light sensor. However, predictive methods are not very suitable for light sensors which are deployed outdoors; a light sensor deployed in a polluted urban area may drift at a substantially faster rate than a light sensor deployed in the
20 countryside, for example.

SUMMARY

An object of the present invention is to provide a convenient method of estimating the drift of a light sensor output, which can be used to adaptively calibrate the
25 light sensor output.

Embodiments of the invention take advantage of an assumption, namely: the amount of light received by an outdoor light sensor over a 365-day period will be similar enough from one year to the next to be used as a reference value for estimating output drift. For instance, say a light sensor output is sampled 10 times per day, every day in the year

2013, and all of the samples are summed together into a total value which is stored for future reference. Then it would be assumed that approximately the same total value should be obtained by carrying out the same sample-and-sum process in, say, 2015, and that any substantial difference between the respective total values is due to output drift.

5 A first aspect of the invention provides an output-drift estimation method for a light sensor output, as recited in claim 1. The method estimates drift based on the light sensor output itself. Therefore, the method does not require separate measurements to be taken, so it can be performed automatically and integrated into a lighting controller or into the light sensor itself, for example. Furthermore, by being based on the light sensor output
10 itself, the method should be relatively robust to different rates of degradation between sensors, as compared with predictive methods of estimating drift.

The expected value mentioned in claim 1 may be representative of a further plurality of samples of the light sensor output, wherein all of the samples of the further plurality were sampled over a further, earlier period of 365 consecutive days. In which case,
15 the expected value will be based on empirical data and is likely to be more accurate than, say, a preset (estimated) value.

A second aspect of the invention provides a computer program product comprising a computer program, as recited in claim 8.

A third aspect of the invention provides a controller as recited in claim 9.

20 A fourth aspect of the invention provides a lighting fixture as recited in claim 10.

It will be appreciated neither the representative value nor the expected value are limited to respective single 365-day periods. Either or both may be based on sensor samples from respective integer multiples of 365 days, such as 2, 3, 4 or 5 consecutive
25 periods of 365 consecutive days.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the invention will now be described with reference to the accompanying drawings, in which:

30 Figure 1 schematically shows a lighting fixture according to an embodiment of the invention;

Figure 2 is a flowchart summarizing a preliminary process performed by a controller of the lighting fixture shown in Figure 1; and

Figure 3 is a flowchart summarizing an output-drift estimation method carried out by the controller, following the preliminary process of Figure 2.

DETAILED DESCRIPTION

5 As shown in Figure 1, an embodiment of the invention provides a lighting fixture 100 comprising a light sensor 110, a lighting unit 120, and a controller 130.

The light sensor 110 is a photodiode configured to output an electrical signal indicative of intensity of light incident thereupon.

10 The lighting unit 120 uses an LED-based light source to provide illumination, under control of the controller 130.

The controller 130 comprises a processor 160, memory 140 and a communications module 150 for communicating with the light sensor 110 and the lighting unit 120. The processor 160 is connected to the memory 140 and the communications module 150. The processor 160 is configured to provide a control signal to the lighting unit 15 120 for controlling the illumination in dependence on the output of the light sensor, and further configured to use the output-drift estimate (obtained via the method described below) to calibrate the output of the light sensor.

In this embodiment, the memory 140 has stored therein one or more programs that, when executed by the processor 160, cause the controller 130 to perform the functions 20 described below.

Referring now to Figure 2, when the lighting fixture 100 is first deployed the controller 130 performs a preliminary process 200 whereby it determines an expected value for later use in estimating output drift.

25 The preliminary process 200 is carried out over a period of 365 days starting on the day the controller 130 is first activated. That day and each subsequent day of the period, the controller 130 receives 210 via the communications module 150 a sample of the output of the light sensor 110.

The controller 130 stores 220 the received sample in the memory 140 and also adds it to a running total of the samples received so far. (On the first day of the period the 30 running total will be zero, or another default value.)

The controller 130 then determines 230 whether the received sample is the n^{th} it has received. In this embodiment n is 365 since, as noted above, the processor receives a respective sample every day over the period of 365 days starting when the controller 130 was first activated. In other embodiments, n may be smaller or greater depending on the rate at

which samples are received over the 365-day period. For instance, the controller 130 might receive one sample per week.

If fewer than n samples have been received, the controller 130 will wait to receive 210 a further sample; in this embodiment, it will be received the following day.

5 In response to determining 230 that the received sample is the n^{th} it has received, the controller 130 stores 240 in the memory 140 the running total of the samples received so far, as a value which is representative of all of the received samples of the light sensor output. Then the preliminary process 200 ends.

10 At the end of the preliminary process 200, in this embodiment, stored in the memory 140 are: the n samples received over the 365-day period; and the representative value, which will be used as an expected value in the drift-estimation process described below.

Reference is now made to Figure 3, which summarizes a drift-estimation method 300 performed each day after the preliminary process 200 has ended.

15 As shown, each day the controller 130 receives 310 via the communications module 150 a further sample of the output of the light sensor 110, and then uses the further sample to compute a new representative value. The new representative value will be representative of a plurality of received samples of the output of the light sensor 110, wherein all of the samples were sampled (and received) over the most recent period of 365
20 consecutive days (i.e. including the further sample, which was received “today”).

To compute the new representative value, the controller 130 retrieves 321 from the memory 140 a previous representative value. The previous representative value is representative of the plurality of samples of the output of the light sensor 110 from the immediately preceding 365 consecutive days (i.e. up to and including “yesterday”). In the
25 first instance, the previous representative value will be the representative value that was determined and stored during the preliminary process 200. The controller 130 also retrieves from memory, and subtracts 322 from the previous representative value, the oldest sample from which the previous representative value was, in part, derived. In the first instance, the oldest sample will be the one that was received on the first day of the preliminary process
30 200. The controller 130 also adds 323 the further sample to the previous representative value. Thus the new representative value is obtained. It will be appreciated that during the first 364 days of the drift-estimation method 300, the most recent period of 365 consecutive days (from which the new representative value is derived) will overlap the initial period of

365 consecutive days from which the expected value is derived, so the respective values will have at least 1 sample in common.

The controller 130 then receives 330 an expected value, which in this embodiment comprises retrieving the expected value from the memory 140. The expected value is the representative value that was determined and stored during the preliminary process 200; thus, with respect to the new representative value, it is representative of a further plurality of samples of the light sensor output, wherein all of the sample of the second plurality were sampled over an (initially overlapping) earlier period of 365 consecutive days.

The controller 130 then uses the expected value and the new representative value to compute 340 an estimate of the drift of the light sensor output; the estimate is proportional to the extent of any difference between those two values, and may e.g. be expressed as a percentage of the expected value.

Finally, the controller 130 stores the further sample and the new representative value, which ends the current iteration of the drift-estimation method 300. In this embodiment, the further sample is stored in replacement of the oldest sample, in order to conserve memory resources.

While embodiments of the invention have been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative and not restrictive; the invention is not limited to the disclosed embodiments.

For example, the preliminary method 200 can be omitted. In an embodiment, suitable replacements for the resulting n samples and the representative value are derived and pre-stored in the memory e.g. "hard-coded" during manufacture. Thus the controller can, in an embodiment, perform the output-drift estimation method 300 as soon as it is deployed.

Also, whereas the sum of samples from a period of 365 consecutive days was used as a representative value, other suitable types of representative value could be used. For instance, the mean, median or mode of the samples could be used.

Further, instead of a single daily sample, the controller could receive a daily value representative of (e.g. an average of) two or more consecutive samples of the output of the light sensor. In which case the controller would be summing and averaging the samples, albeit with averaging being performed by the sensor. For instance, the light sensor could provide a daily integrated (i.e. averaged) output. The integrated output could comprise a value which is the average of samples taken at 1-minute intervals over a 24-hour period.

Preferably, the sampling rate would be no less than the Nyquist rate, but aberrations caused by subsampling should average to 0 so sampling at less than the Nyquist rate is acceptable.

Also, whereas the controller received samples and computed a value representative thereof, the representative value may be computed elsewhere (e.g. in the sensor itself) and forwarded to the controller for comparison with the expected value.

In various embodiments, the lighting fixture 100 may be any arrangement of one or more lighting units in a particular form factor, assembly, or package. A given lighting unit may include one or more light sources of same or different types, and may have any one of a variety of mounting arrangements for the light source(s), enclosure/housing arrangements and shapes, and/or electrical and mechanical connection configurations. Additionally, a given lighting unit optionally may be associated with (e.g., include, be coupled to and/or packaged together with) various other components (e.g., control circuitry) relating to the operation of the light source(s).

In various embodiments, the light source may be any one or more of a variety of radiation sources. These include LED-based sources, incandescent sources (e.g., filament lamps, halogen lamps), fluorescent sources, phosphorescent sources, high-intensity discharge sources (e.g., sodium vapor, mercury vapor, and metal halide lamps), lasers, other types of electroluminescent sources, pyro-luminescent sources (e.g., flames), candle-luminescent sources (e.g., gas mantles, carbon arc radiation sources), photo-luminescent sources (e.g., gaseous discharge sources), cathode luminescent sources using electronic saturation, galvanoluminescent sources, crystallo-luminescent sources, kine-luminescent sources, thermo-luminescent sources, triboluminescent sources, sonoluminescent sources, radioluminescent sources, and luminescent polymers.

In various embodiments, the light sensor may be any device configured to provide a signal indicative of one or more aspects of light when exposed thereto. Light sensors can further comprise light filters or other optical elements which can be used to affect the response characteristics of the light sensor, for example by increasing or decreasing responsiveness to incident light at one or more wavelengths.

In various embodiments, the memory may be any suitable storage media, such as one or more of: volatile and non-volatile computer memory such as RAM, PROM, EPROM, and EEPROM, floppy disks, compact disks, optical disks, magnetic tape, etc. Various storage media may be fixed within the processor and/or controller, or may be transportable, such that the one or more programs stored thereon can be loaded into a processor or controller so as to implement various aspects of the present invention discussed

herein. The terms “program” or “computer program” are used herein in a generic sense to refer to any type of computer code (e.g., software or microcode) that can be employed to program one or more processors or controllers.

Other variations to the disclosed embodiments can be understood and effected
5 by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality.

A single processor or other unit may fulfill the functions of several items
10 recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS:

1. An output-drift estimation method (300) for a light sensor output, comprising:
 - obtaining (320) a value representative of a plurality of samples of the light sensor output, wherein all of the samples were sampled over at least one period of 365 consecutive days;
 - 5 - determining a difference between the received value and an expected value; and
 - computing (340) an output-drift estimate based on the determined difference.
2. The method (300) of claim 1, wherein the plurality of samples comprises at
10 least one sample from each day of said at least one period.
3. The method (300) of claim 1 or claim 2, wherein the expected value is representative of a further plurality of samples of the light sensor output, wherein all of the samples of the further plurality were sampled over at least one further, earlier period of 365
15 consecutive days.
4. The method (300) of claim 3, wherein the further plurality of samples comprises at least one sample from each day of the at least one further period.
- 20 5. The method (300) of any one of claims 3 to 4, wherein at times the plurality of samples and the further plurality of samples have at least one sample in common.
6. The method (300) of any foregoing claim, further comprising computing (340) the value representative of the plurality of samples by at least: summing and/or averaging all
25 of the samples of the plurality of samples.
7. The method (300) of claim 3, or any foregoing claim dependent on claim 3, further comprising computing the expected value by at least: summing and/or averaging all of the samples of the further plurality of samples.

8. A computer program product comprising a computer program which, when executed by a suitably arranged processor (106) , configures the processor (160) to perform the method (300) of any foregoing claim.

5

9. A controller (130) comprising:

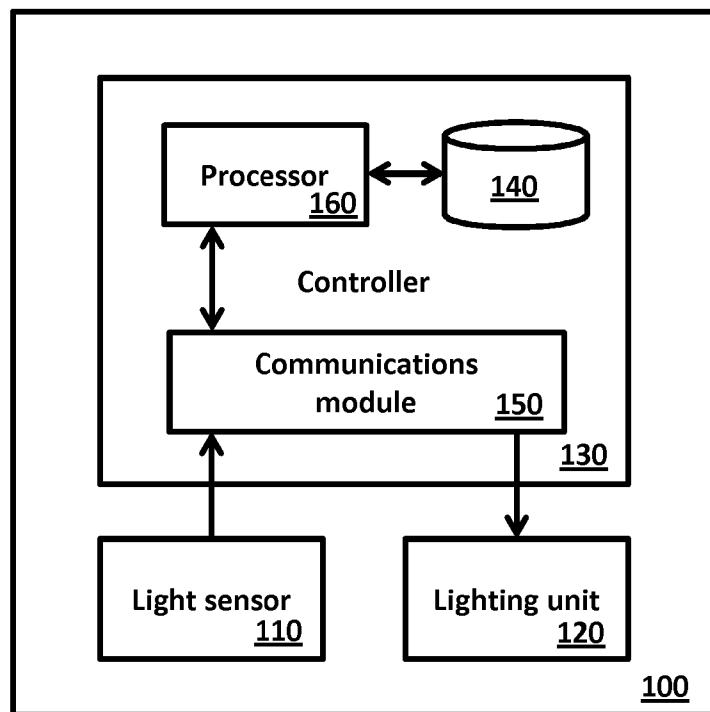
- communications circuitry (150) for sending and receiving data;
- memory (140) comprising a computer program; and
- a processor (160) connected to the communications circuitry (150) and the

10 memory (140), which is operable to execute the computer program and to be configured thereby to perform the method of any one of claims 1 to 7.

10. A lighting fixture (100) comprising:

- a light sensor (110) arranged to provide a light sensor output;
- 15 - a lighting unit (120) arranged to provide illumination; and
- the controller (130) of claim 9, arranged to receive the light sensor output and to provide a control signal to the lighting unit (120) for controlling the illumination in dependence on the light sensor output, and further arranged to use the output-drift estimate to compensate for drift in the light sensor output.

20

**Figure 1**

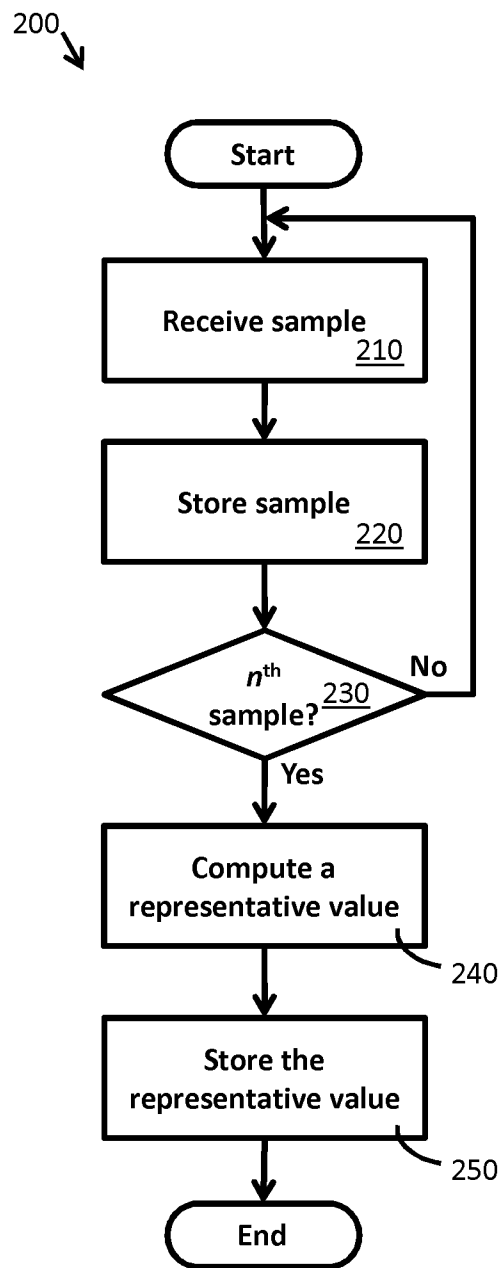


Figure 2

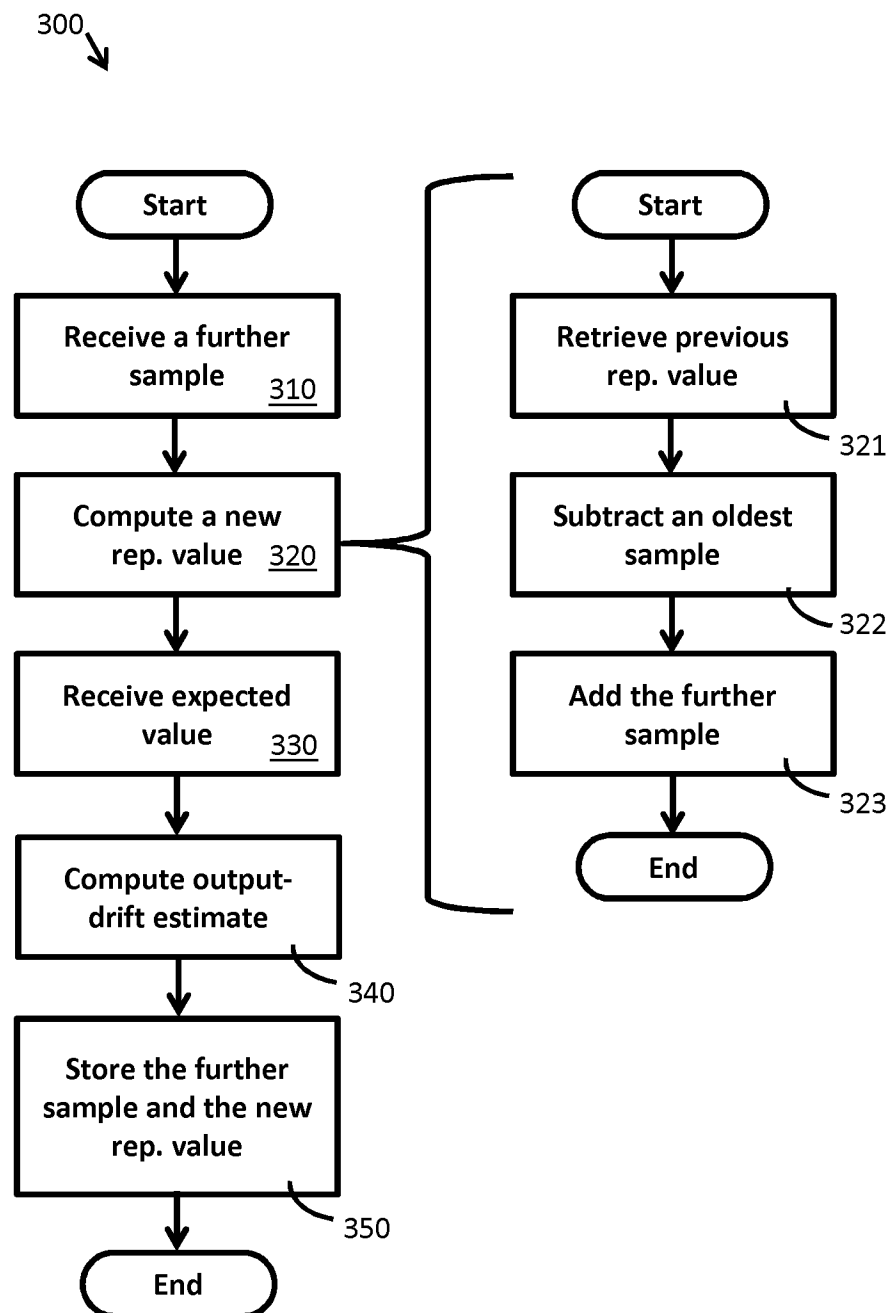


Figure 3

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2013/059224

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01J1/02 G01J1/42
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2009 058342 A (SEIKO EPSON CORP) 19 March 2009 (2009-03-19) paragraphs [0002] - [0029]; figures 1-4 -----	1-10
A	JP 2009 257813 A (EPSON IMAGING DEVICES CORP) 5 November 2009 (2009-11-05) cited in the application abstract -----	1-10
A	JP H10 185615 A (DIAMOND ELECTRIC MFG) 14 July 1998 (1998-07-14) abstract -----	1-10
A	US 2008/319695 A1 (ISHII RYO [JP] ET AL) 25 December 2008 (2008-12-25) paragraphs [0009] - [0022] -----	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report		Publication date	Patent family member(s)	Publication date
JP 2009058342	A	19-03-2009	NONE	
JP 2009257813	A	05-11-2009	NONE	
JP H10185615	A	14-07-1998	NONE	
US 2008319695	A1	25-12-2008	CN 101329199 A	24-12-2008
			JP 2009002661 A	08-01-2009
			KR 20080112104 A	24-12-2008
			US 2008319695 A1	25-12-2008