



- (51) **International Patent Classification:**
G01J 5/02 (2006.01) H04N 5/33 (2006.01)
- (21) **International Application Number:**
PCT/SE2013/000195
- (22) **International Filing Date:**
16 December 2013 (16.12.2013)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
1230150-3 18 December 2012 (18.12.2012) SE
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(81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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(54) **Title:** SENSOR CALIBRATION METHOD, COMPUTER PROGRAM AND COMPUTER READABLE MEDIUM

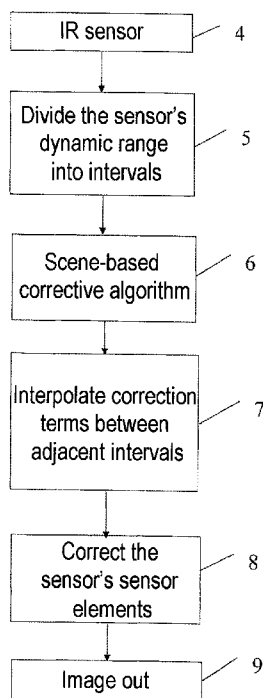


Fig.3

(57) **Abstract:** The invention relates to a method for the calibration of sensors of the type that comprises a plurality of sensor elements, such as focal plane arrays, FPAs, for detecting infrared radiation, IR-FPA, the calibration being performed at least two temperatures. According to the invention, the sensor's dynamic range is divided into a plurality of intervals (5), a correction map is updated on a running basis in each interval by a scene-based non-uniformity correction (6), the correction terms between adjacent intervals are interpolated (7), and the interpolated correction terms are made to correct the sensor elements of the relevant sensor (8). The invention also relates to a computer program and a computer program product. By way of the invention, a method is provided which effectively minimizes the fixed pattern noise to near zero across the entire dynamic range of the sensor, regardless of the type of non-linearity.



Published:

— *with international search report (Art. 21(3))*

**Sensor calibration method, computer program and
computer readable medium**

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Field of the invention

The present invention relates to a method for the calibration of sensors of the type that comprises a plurality of sensor elements, such as focal plane arrays, FPAs, for detecting infrared radiation, IR-FPA, the calibration being performed at at least two temperatures. The invention also relates to a computer program comprising program code, which, when said program code is executed on a computer, causes said computer to perform the method, as well as a computer program product comprising a computer readable medium and a computer program according to the above, said computer program being comprised in said computer readable medium.

Background

The output signal from the sensor elements of a sensor, such as an IR-FPA, can vary quite considerably as a function of incident power. The sensor elements therefore need to be calibrated between themselves. For example, the sensor elements included in a sensor of an IR camera do not behave the same way, but exhibit variations in gain and offset. To handle these variations, so-called gain and offset maps are included and stored in production. The gain map is used during operation to correct for gain variations in the individual sensor elements of a sensor. Correspondingly, the offset map is used during operation to parallel offset the sensor signals of the included sensor elements so that the gain curves of the detectors substantially coincide. To further elucidate the principles behind gain and offset mapping, reference is

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made to our published U.S. patent application US 2011/0164139 A1.

A common way to calibrate the sensor of a camera is to let the camera watch perfectly flat black body radiators at different temperatures. In case the non-linearity between the different sensor elements is the same, with variations only in gain and offset level, it is sufficient to calibrate the sensor against two different temperatures, so-called two-point correction. In many cases, however, this requirement for non-linearity between sensor elements is not met, especially in extreme temperatures or when sensors with poor uniformity are used. One solution has then been to calibrate against black body radiators at several temperatures. To cover the entire dynamic range, the response of each individual detector element must be measured across the entire dynamic range. Such a solution, however, has several disadvantages. Among other things, the solution is tedious and requires unreasonably long time during production. Also, the solution requires large memory capacity.

Summary of the invention

The purpose of the present invention is to provide a method that corrects for gain and offset, and the difference in non-linearity, thereby effectively minimizing fixed pattern noise without tedious measurement of individual detector elements during production.

The purpose of the invention is achieved by a method characterized in that the sensor's dynamic range is divided into a plurality of intervals with respect to temperature, that a correction map is updated on a running basis in each interval by a scene-based non-uniformity correction, that the correction terms between adjacent intervals are interpolated, and that

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the interpolated correction terms are made to correct the sensor elements of the relevant sensor.

By way of the proposed method, an effective
5 minimization of the fixed pattern noise to near zero across the sensor's entire dynamic range is achieved, without doing it the traditional way, where the response of each detector element must be measured across the entire dynamic range, the latter of which
10 can be extremely tedious. Moreover, the method is independent of the type of non-linearity exhibited by the detector elements.

According to a proposed suitable method, the sensor's
15 dynamic range is divided into at least three intervals.

According to another proposed suitable method, the number of intervals that the dynamic range is divided into is increased if greater accuracy of the
20 calibration is required.

According to a further proposed suitable method, the correction map is updated on a running basis in the middle of each interval.
25

According to yet another proposed suitable method, the scene-based non-uniformity correction consists of a scene-based corrective algorithm.

30 Furthermore, according to a suitable method, it is proposed that the sensor elements of a focal plane array are calibrated.

Brief description of the drawing
35

The invention will be further described below by way of example with reference to the accompanying drawing wherein:

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Figure 1 schematically shows an IR sensor with a plurality of sensor elements.

5 Figure 2 shows examples of the gain of some sensor elements included in an IR sensor as a function of temperature.

Figure 3 shows a schematic flowchart illustrating the
10 principles behind the invention.

Detailed description of the embodiment

The IR sensor 1 showed in Figure 1 comprises $m \times n$
15 sensor elements $S_{1,1} - S_{m,n}$, distributed across m rows and n columns. The sensor can consist of a focal plane array, IR-FPA. Each individual sensor element $S_{1,1} - S_{m,n}$ included in the sensor 1 can have its own gain curve.

20 Figure 2 shows examples of some gain curves 2.1, 2.2 and 2.3 as a function of the temperature T . As shown in the figure, the individual gain curves can exhibit very different curve shapes. Vertical lines divide the sensor's dynamic range into intervals. In Figure 2 four
25 ranges 3.1-3.4 have been marked. In case the sensor elements have very different shapes, an even more extensive division of the sensor's dynamic range into intervals is required than if the curve shapes of the sensors are similar.

30

The principles behind the invention will be explained below with reference to the schematic flowchart shown in Figure 3.

35 An IR sensor included in Block 4 delivers an image to Block 5. In Block 5 the sensor's dynamic range is divided into intervals 3.1, 3.2, 3.3, etc. In the middle of each interval, a correction map created by

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some kind of scene-based corrective algorithm of known type is updated on a running basis according to Block 6. Then, in Block 7, the correction terms are interpolated between adjacent intervals. The obtained interpolated
5 correction terms correct the sensor elements with respect to both gain and offset, and for differences in non-linearity, which is performed in Block 8 by letting the interpolated correction terms correct the sensor elements of the relevant sensor using the obtained
10 interpolated correction terms for the current temperature range so that a corrected image can be delivered, Block 9. The accuracy of the non-linearity correction depends on the number of intervals; several short intervals means greater accuracy. Theoretically,
15 using an infinite number of small intervals, the method can manage an arbitrary variation between the sensor elements.

The invention is not restricted to the exemplary method
20 described above, but can be subject to modifications within the scope of the appended claims.

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Claims

1. Method for the calibration of sensors of the type comprising a plurality of sensor elements (4),
5 such as focal plane arrays, FPAs, for detecting infrared radiation, IR-FPA, the calibration being performed at at least two temperatures, characterized in that the sensor's dynamic range is divided into a plurality of intervals (5) with
10 respect to temperature, that a correction map is updated on a running basis in each interval by a scene-based non-uniformity correction (6), that the correction terms between adjacent intervals are interpolated (7), and that the interpolated
15 correction terms (8) are made to correct the sensor elements of the relevant sensor.
2. Method according to Claim 1, **characterized in that** the sensor's dynamic range is divided into at
20 least three intervals (3.1-3.4).
3. Method according to any one of the preceding claims, **characterized in that** the number of intervals that the dynamic range is divided into
25 is increased if greater accuracy of the calibration is required.
4. Method according to any one of the preceding claims, **characterized in that** the correction map
30 is updated on a running basis in the middle of each interval.
5. Method according to any one of the preceding claims, **characterized in that** the scene-based non-uniformity correction (6) consists of a scene-based corrective algorithm.
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6. Method according to any one of the preceding claims, **characterized in that** the sensor elements ($S_{1,1} - S_{m,n}$) of a focal plane array are calibrated.
- 5 7. Computer program comprising program code, which, when said program code is executed on a computer, causes said computer to perform the method according to any one of Claims 1-6.
- 10 8. Computer program product comprising a computer readable medium and a computer program according to Claim 7, said computer program being comprised in said computer readable medium.

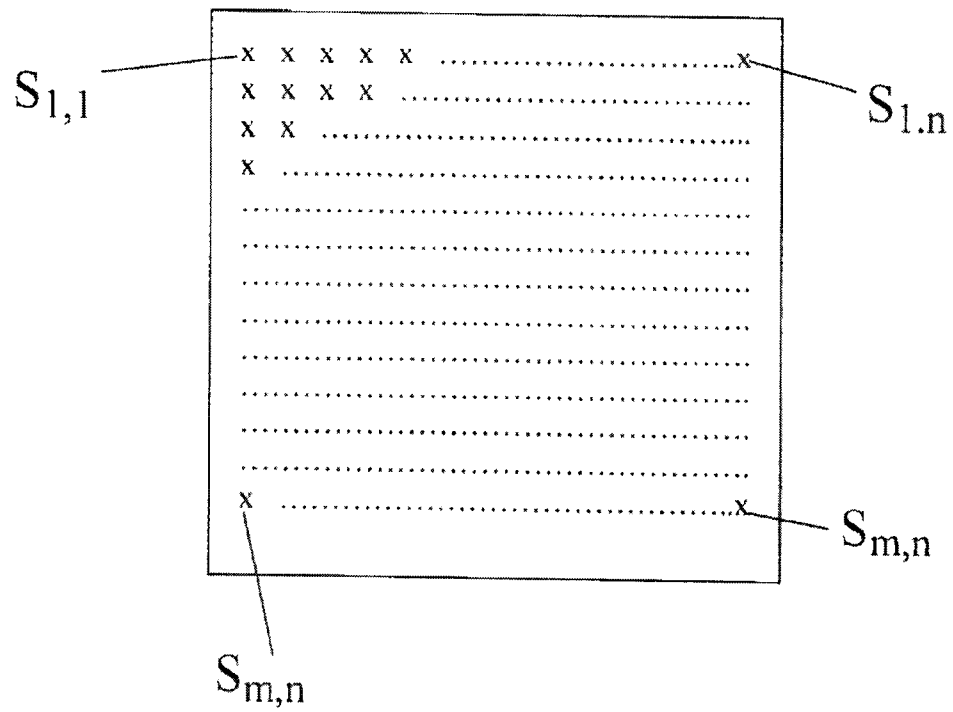


Fig. 1

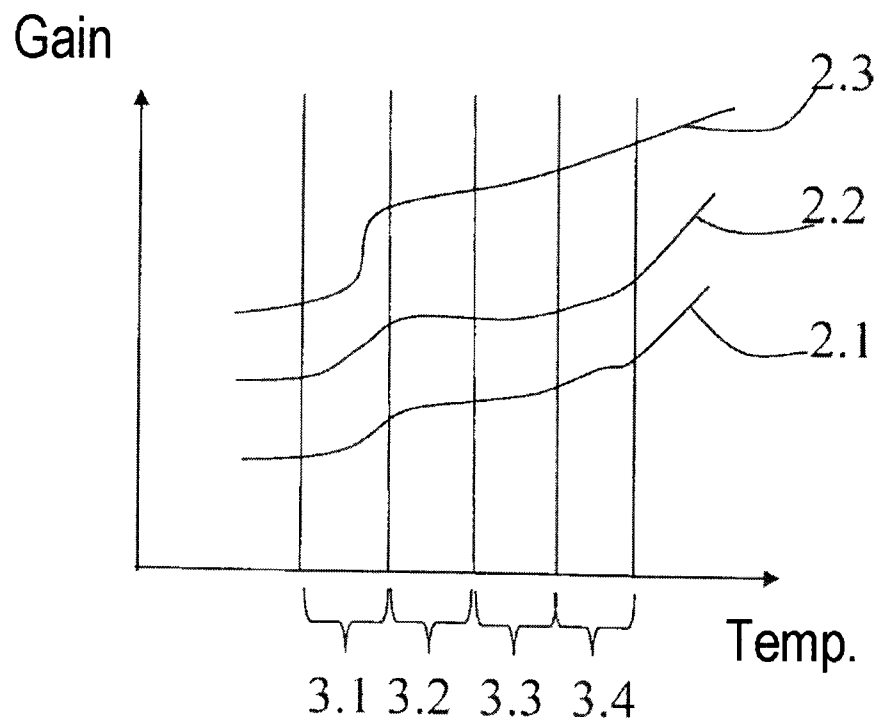


Fig.2

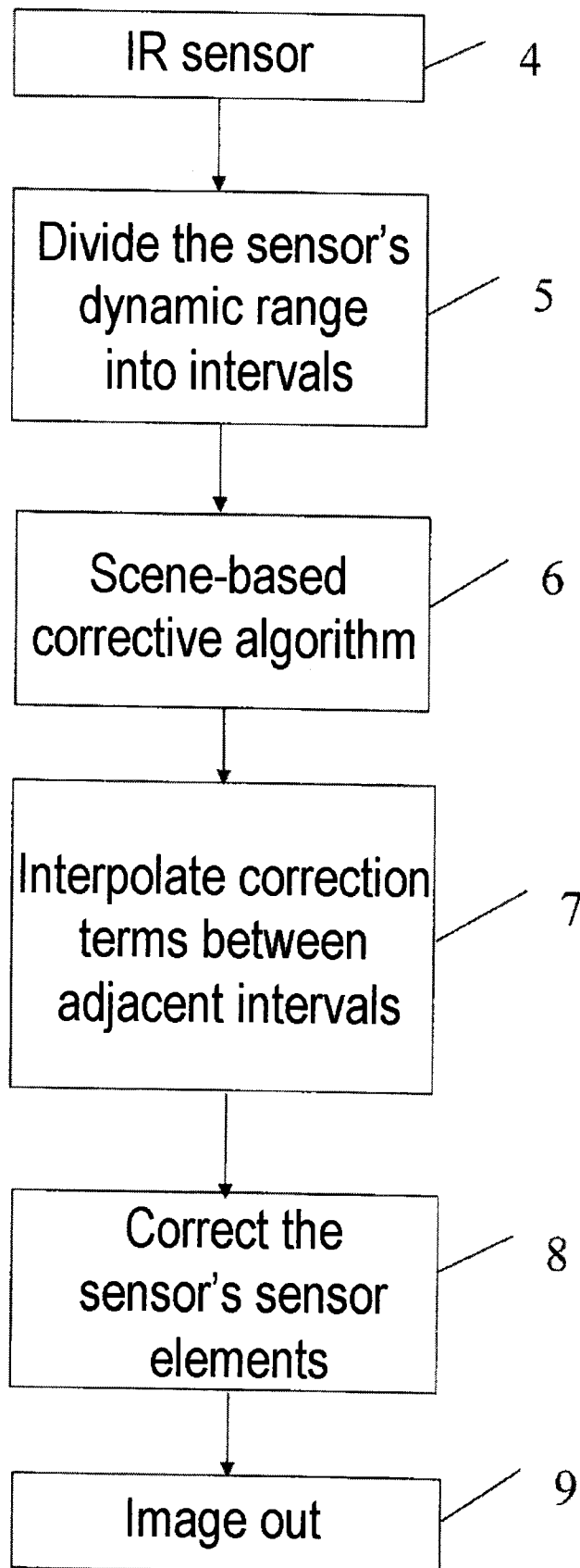


Fig.3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2013/000195

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: G01J, H04N

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20090273675 A1 (JONSSON HENRIK), 5 November 2009 (2009-11-05); abstract; paragraphs [0016]-[0069]; figures 4,5 --	1-8
A	US 6324308 B1 (CHEN PEIYI ET AL), 27 November 2001 (2001-11-27); abstract; column 1, line 10 - column 2, line 7 --	1-8
A	US 20050205785 A1 (HORNBACK BERT ET AL), 22 September 2005 (2005-09-22); abstract --	1-8
A	US 20090272888 A1 (NUGENT PAUL W ET AL), 5 November 2009 (2009-11-05); abstract --	1-8

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

☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“E” earlier application or patent but published on or after the international filing date

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“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

04-04-2014

Date of mailing of the international search report

04-04-2014

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2013/000195

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20110168890 A1 (STRANDEMAR KATRIN ET AL), 14 July 2011 (2011-07-14); abstract --	1-8
A	Pipa D. et al., Recursive Algorithms for Bias and Gain Nonuniformity Correction in Infrared Videos, IEEE Transactions on image processing, 2012, vol 21, no 12, 4758-4769; abstract -- -----	1-8

Continuation of: second sheet**International Patent Classification (IPC)****G01J 5/02** (2006.01)**H04N 5/33** (2006.01)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SE2013/000195

US	20090273675 A1	05/11/2009	NONE	
US	6324308 B1	27/11/2001	NONE	
US	20050205785 A1	22/09/2005	US	7235785 B2 26/06/2007
US	20090272888 A1	05/11/2009	NONE	
US	20110168890 A1	14/07/2011	NONE	