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PI 2010002625 7 June 2010 (07.06.2010) MY(71) Applicant (for all designated States except US): **MIMOS BERHAD** [MY/MY]; Technology Park Malaysia, 57000 Kuala Lumpur (MY).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **HON, Hock Woon** [MY/MY]; Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY).(74) Agent: **DAMODHARAN, Ramakrishna**; KASS International Sdn. Bhd., Suite 8-7-5 Menara Mutiara Bangsar, Jalan Liku Off Jalan Riong, Bangsar, 59100 Kuala Lumpur (MY).

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(54) Title: A METHOD OF DETERMINING AN OPTIMUM TRANSFORMATION POINT

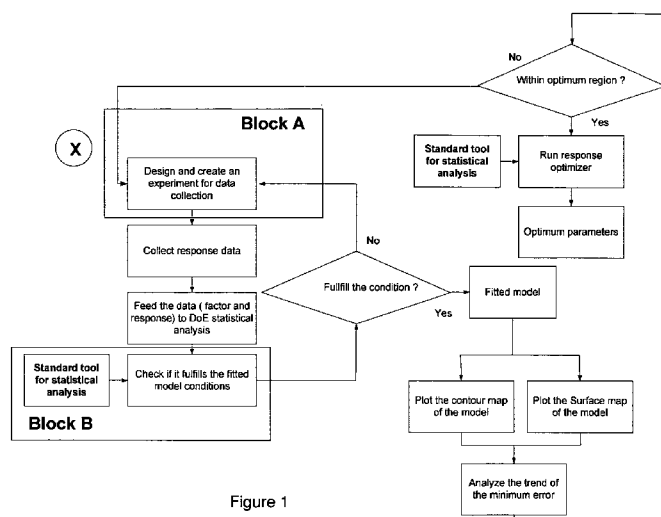


Figure 1

(57) **Abstract:** A method of determining an optimum transformation point which produces minimal transformation errors from data collected from an experiment is provided, the method includes the steps of determining that a lack of fit error from the data is less than a predetermined ratio, determining that a probability value from the data is larger than the predetermined ratio, determining that a curvature error from the data is less than the predetermined ratio, determining that a coefficient of determination, R^2 from the data is more than a fixed ratio, determining that a difference between the R^2 value and an adjusted R^2 value is less than a preset ratio, wherein a fitted model is then created upon fulfillment of all conditions above, plotting a pixel error distribution data with a contour and surface map to visualize the fitted model and running a standard response optimizer to obtain optimum parameters to achieve a desired value.

A METHOD OF DETERMINING AN OPTIMUM TRANSFORMATION POINT

FIELD OF INVENTION

- 5 The present invention relates to a method of determining an optimum transformation point which produces minimal transformation errors from data collected from an experiment.

BACKGROUND OF INVENTION

10

Usually cameras and lenses that are used in cameras are produced by different manufacturers. Therefore, the alignment between the two is not accurately calibrated for optimum use. As alignment of the lens and camera determines accuracy of transformation error, the transformation error is found to determine visual quality of processed video. The transformation error is caused by an approximate 10 % misalignment of the lens and the camera used in any optical system.

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The alignment between camera and the lens are usually not perfect under normal conditions where there are no special unit calibrations. This problem worsens when a lens or camera sensor is not perfectly geometrically shaped. This imperfection usually translates to a distorted video image in any imaging system.

20

U.S 5,581,347 describes a method and a device for measuring a geometrical optical structure and a calculating procedure between a result surface and a measured surface. However, the described invention depends heavily on reflected light of an optical component which may also result in faulty results while performing the calculations as uncalibrated apparatus may introduce more errors in calculation.

25

Therefore, there exists a need in the field to produce a reliable method of detection and determining an optimized transformation point without relying only on apparatus.

SUMMARY OF INVENTION

- Accordingly there is provided a method of determining an optimum transformation point which produces minimal transformation errors from data collected from an experiment,
- 5 the method includes the steps of determining that a lack of fit error from the data is less than a predetermined ratio, determining that a probability value from the data is larger than the predetermined ratio, determining that a curvature error from the data is less than the predetermined ratio, determining that a coefficient of determination, R2 from the data is more than a fixed ratio, determining that a difference between the R2 value
- 10 and an adjusted R2 value is less than a preset ratio, wherein a fitted model is then created upon fulfillment of all conditions above, plotting a pixel error distribution data with a contour and surface map to visualize the fitted model and running a standard response optimizer to obtain optimum parameters to achieve a desired value.
- 15 The present invention consists of several novel features and a combination of parts hereinafter fully described and illustrated in the accompanying description and drawings, it being understood that various changes in the details may be made without departing from the scope of the invention or sacrificing any of the advantages of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be fully understood from the detailed description given herein below and the accompanying drawings which are given by way of illustration only, and
5 thus are not limitative of the present invention, wherein:

Figure 1 is a flowchart showing the steps taken in an embodiment of a method of optimizing transformation error;

Figure 2 is a flowchart showing the steps taken in Block B of the embodiment of a method of optimizing transformation error;

10 Figure 3 is a flowchart showing the steps taken in Block A of the embodiment of a method of optimizing transformation error;

Figure 4 is a contour plot showing the error distribution between the center point of camera versus center point of lens in the embodiment of a method of optimizing transformation error; and

15 Figure 5 is a contour plot and surface plot showing error distribution between the center point of camera versus center point of lens in the embodiment of a method of optimizing transformation error.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention relates to a method of determining an optimum transformation point which produces minimal transformation errors from data collected from an experiment. A detailed description of preferred embodiment of the invention is disclosed herein. It should be understood, however, that the disclosed preferred embodiment are merely exemplary of the invention, which may be embodied in various forms. Therefore, the details disclosed herein are not to be interpreted as limiting, but merely as the basis for the claims and for teaching one skilled in the art of the invention.

The following detailed description of the preferred embodiment will now be described in accordance with the attached drawings, either individually or in combination.

While the following description may describe example embodiment of the present invention in relation to intelligent imaging, the invention is not limited to and can be applicable to other types of transformation errors where similar advantages may be obtained. Such transformation errors for which inventive embodiments may be applicable specifically include optical systems such as lens and camera optics.

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Figure 1 depicts a flow chart showing a method of determining an optimum transformation point which produces minimal transformation errors from data collected from an experiment. In this embodiment, the method is used to reduce transformation error due to various physical factors such as optical misalignment, shape of lens, displacement between camera and lens. Optimum transformation point in this description refers to a transformation point that produces minimized amount of error using the method. The method includes the steps of determining that a lack of fit error

from the data is less than a predetermined ratio (in this description the term 'percentage' and 'ratio' are used interchangeably), determining that a probability value from the data is larger than the predetermined ratio, determining that a curvature error from the data is less than the predetermined ratio, determining that a coefficient of determination, R2 from the data is more than a fixed ratio, determining that a difference between the R2 value and an adjusted R2 value is less than a preset ratio, wherein a fitted model is then created upon fulfillment of all conditions above, plotting a pixel error distribution data with a contour and surface map to visualize the fitted model and running a standard response optimizer to obtain optimum parameters to achieve a desired value.

Transformation performance problem is tackled by reducing amount of errors generated through a method of determining an optimum transformation point. The method is mainly affected by alignment between a camera lens and a camera.

Normally, the alignment between camera and lens is not perfect unless any special calibration is conducted. The problem becomes worse if either the lens or camera sensor position and shape are not perfect. Imperfections of lens and camera alignment manifest itself in skewed video images.

The first step is to design and create an experiment for data collection. Upon creation of the experiment, response data is collected. The experiment includes setting parameters including centre point X, centre point Y from an image obtained from a combination of said lens and camera as well as radius used for transformation. These three factors form main determining parameters for quality of the transformed outcome.

As there are three main factors, three-factor full factorial experiment is chosen.

The response data, which is representative of experimental outcome, is then fed into a statistical tool for model fitting. The response data in this case refers to a plurality of error transformed pixels. This can be quantified by measuring the plurality of bad/ error pixels in an output image. The plurality of error transformed pixels is used as a
5 quantitative measure for the quality of the output data.

Statistical methods such as design of Experiment (DoE) and Response Surface Methodology (RSM) can be used for the purpose of analysis. The selected statistical method returns at least one indicator wherein a further set of steps are applied to the
10 indicator to check predetermined criteria to ensure a model is best fitted. If a model is not fitted, the steps are to be repeated until a fitted model is obtained. Once all predetermined criteria are fulfilled, the best fitted model can be used to determine an optimum transformation point.

15 The predetermined criteria are based on assumptions such as lack of fit error must be less than a preset ratio. Further, more assumptions are made such as curvature error values must not exceed a predetermined ratio as well as other statistical limitations.

A contour map and a surface map are created to visualize the fitted model. The maps
20 provide information of the trend to the optimum point. This can be seen by observing a direction trend of the minimum error. Optimum setting trends are analyzed using the contour map and surface map as seen in Figure 4 and Figure 5. If requirements for preset transformation error value are fulfilled, run the fitted model through a standard response optimizer to obtain optimum parameters to achieve a desired value.
25 However, if the preset requirements are not fulfilled, it is necessary to go back and recreate the model again through the steps of Block A as seen in Figure 1 and 3.

Upon obtaining optimum parameters to achieve the desired value, the optimum parameters are fed into the model and response from the model is measured. Finally, verification that the requirement has been met is done.

- 5 In Figure 1 and 3, it is seen that there are two sets of steps to be followed which include Block A and Block B. A flowchart enlisting all steps for Block A is shown in Figure 3 and a flowchart enlisting all steps for Block B is shown in Figure 2. In this embodiment of Block A, an experiment is created where all factors affecting the experiment is considered. This is usually done by expert judgment by one skilled in the art of the experiment. However, even if an expert is not available or if the factors considered are not complete, the method is still carried out as there are other statistical tests that will take care of a lack of fit or missing factors in a later stage of the method. Once the factors are determined, the experiment will produce a response which translates to a transformation error. A plurality of parameters is selected to be input factors in the experiment.

- For example, in this embodiment using a camera and a camera lens, there are 3 input parameters which are centre point X, centre point Y and radius. In order to more effectively determine an optimum point, estimation for the input parameters need to be obtained. This is usually done by way of expert judgment or by any range of input data. Permutations of input based on factors are created wherein transformation processes are performed to record all errors that occur. The errors are defined in this embodiment as a number of error pixels per total pixels in terms of ratio or percentage.

- 25 As seen in Figure 2, Block B further indicates that a standard statistical tool can be used to get a statistical value such as lack of fit error, curvature error and P value. P-value is defined as a decision making measure based on statistics wherein it provides

a probability value where Null hypothesis is true. These statistical values are used to modify the model developed in Block A. In this part of the method, interpretation of the statistical value is done and the experiment that was created earlier is modified in order to produce a best fit model as much as possible. As seen in Figure 2, the R2 value
5 must be more than 90% in the preferred embodiment of the invention. Further, the difference between the R2 value and the adjusted R2 value must be less than 10% in the preferred embodiment of the invention.

Figure 1 shows that upon producing a best fit model, a contour map of the model is
10 plotted. A path of accent is determined by analyzing shapes and contours of the map. The path of accent is defined by a direction of the optimum point that is to be determined.

A centre point is determined by using the method of determining the optimum point. In
15 this example, actual parameters have been used and recorded as shown below. As a centre point of a camera is the same as a centre point of the lens, therefore the centre point of a camera (X) is calculated to be total pixels of the camera divided by 2, which is 1280 divided by 2 in this case. Similarly, the centre point of the lens (Y) is calculated to be total pixels of the lens divided by 2, which is 1024 divided by 2. Misalignment of
20 the camera and lens is estimated to be approximately 10%. Therefore, ranges for centre points of camera and lens (X,Y) are set based on $\pm 10\%$ of the calculated values. In this example, the range is set at X = 576 to 704 and Y = 462 to 562.

	Low	High
Centre Point (X)	576	704
Centre Point (Y)	462	562
Radius (R)	450	470
Methods	Three-factor full factorial Design of Experiment or Centre composite face-centered (CCF)	

Table 1

Maximum allowable radius (R) of the lens and camera is 470. It is to be understood
 5 that use of maximum value would maximize pixels used in an output image. However,
 a variation of 20 pixels between 450 and 470 is used in this experiment for variability.

As there are three factors in this experiment, a full factorial Design of Experiment is
 conducted as seen in Table 1 above. Upon conducting the full factorial experiment, it is
 10 concluded that the full factorial experiment is unable to model a relationship between
 the factors efficiently. Accordingly, another statistical method of Response Surface
 Methodology (RSM) is tested next.

The optimum point is expected to be around a centre of the image wherein a direction
 15 of said optimum point is known. Therefore, a central composite face-centered design
 method is selected next.

Items in the model are reduced in order to produce a significant model. When a model
 is more than 90% significant and radius (R) and R² values are less than 10%, the

model is considered to be significant, as seen in Figure 4. In order to maximize useful data, overlapping region between camera and lens is considered in Figure 4. Block RSM is found to be useful when transformation radius (R) is fixed at a maximum value and RSM is re-conducted. A transformation model of RSM between the camera and the lens is shown in Figure 5 and an optimum point is derived from a response optimizer. Therefore, for this experiment, error pixel percentage overall performance is not within predicted limits of the model. However, it is to be appreciated that the error pixel percentage is very close to the model's lower limit. In terms of the model performance, it can be understood that it is more desirable for the predicted error pixel percentage to be closer to the lower limits of the model.

Finally, the optimum points that have been derived are fed back to the original model. Verification if the transformation error has achieved the expected values is conducted to ensure that the model is as complete as possible.

15

It is to be understood that the embodiments of the invention described are exchangeable for other variations of the same in order to be used in various applications. The present embodiment of the invention is intended for, but not restricted to, use in experimental method that requires determining an optimum point.

20

CLAIMS

1. A method of determining an optimum transformation point which produces minimal transformation errors from data collected from an experiment, the method includes the steps of:
 - 5 i. determining that a lack of fit error from the data is less than a predetermined ratio;
 - ii. determining that a probability value from the data is larger than the predetermined ratio;
 - iii. determining that a curvature error from the data is less than the
10 predetermined ratio;
 - iv. determining that a coefficient of determination, R^2 from the data is more than a fixed ratio;
 - v. determining that a difference between the R^2 value and an adjusted R^2 value is less than a preset ratio, wherein a fitted model is then created
15 upon fulfillment of all conditions above;
 - vi. plotting a pixel error distribution data with a contour and surface map of the error distribution to visualize the fitted model; and
 - vii. running a standard response optimizer to obtain optimum parameters to achieve a desired value.
20
2. The method as claimed in claim 1, wherein the contour and surface map of the error distribution is used to analyze optimum setting trends.
3. The method as claimed in claim 1, wherein the optimum parameters obtained from
25 the standard response optimizer are further verified by measuring the response.

4. The method as claimed in claim 1, wherein if a model is not fitted, the steps are to be repeated until a fitted model is obtained.
5. The method as claimed in claim 1, wherein the method of determining an optimum transformation point is used in an optical system.
6. The method as claimed in claim 1, wherein the collected data is analyzed by statistical tools.
- 10 7. The method as claimed in claim 1, wherein the analysis of optimum setting trends is done using statistical methods such as Design of Experiment.

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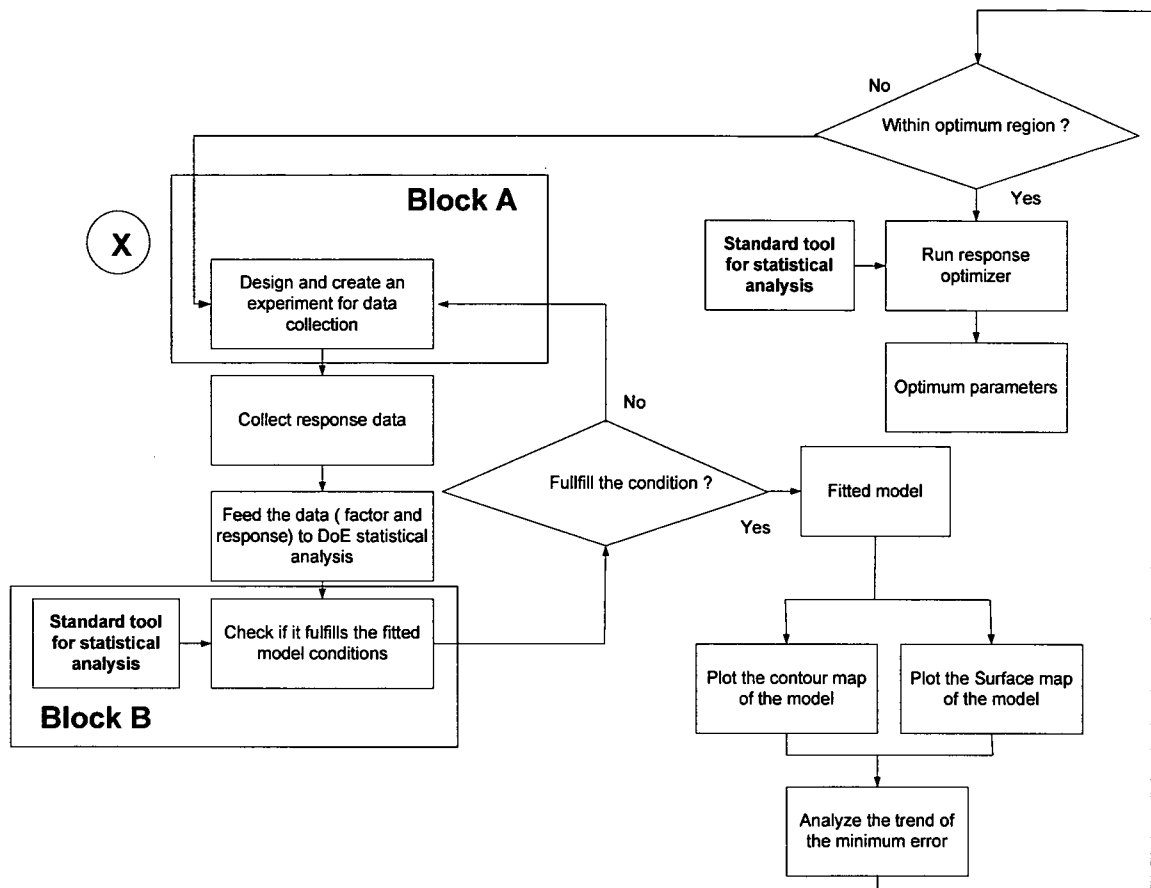


Figure 1

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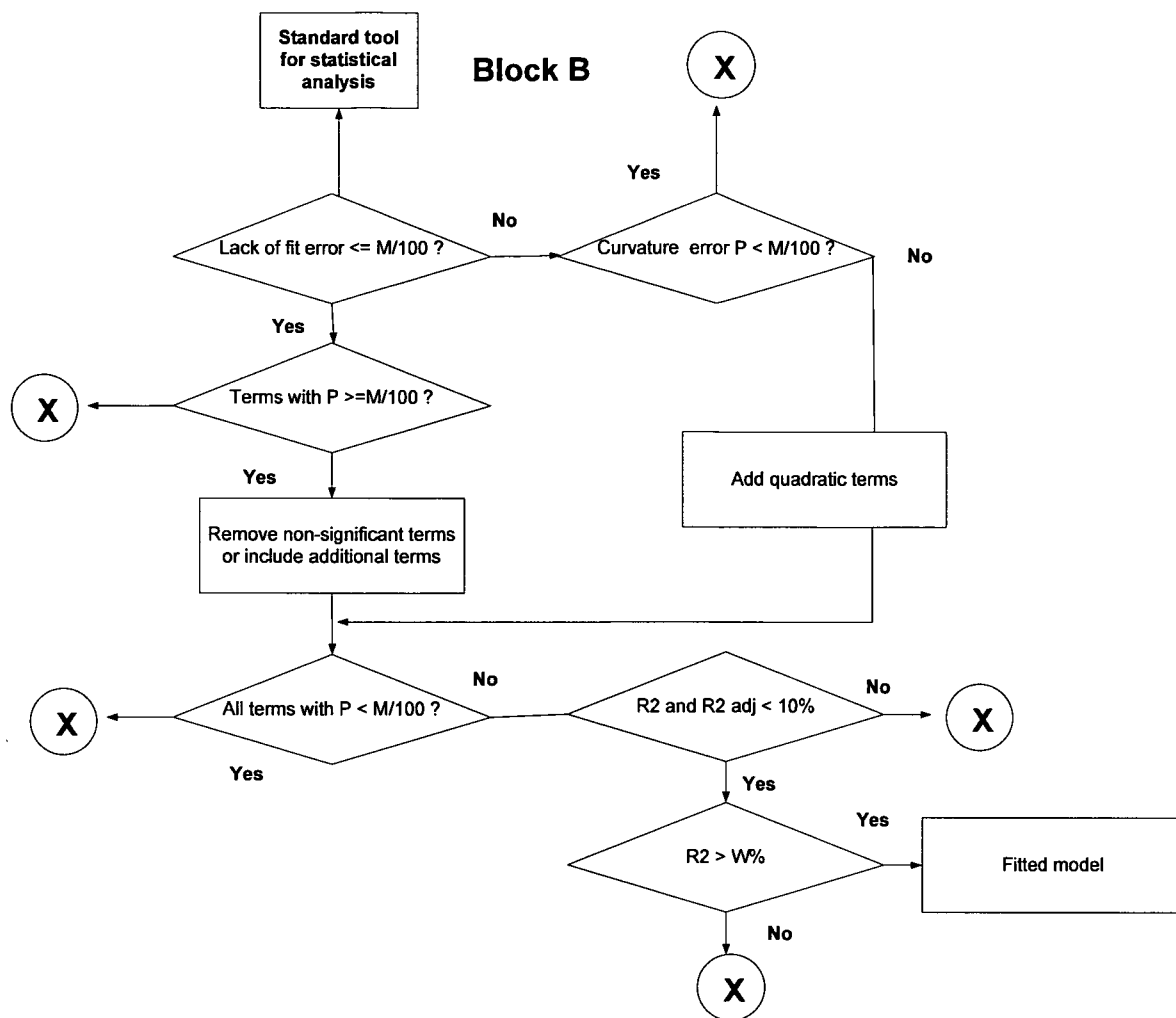


Figure 2

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Block A

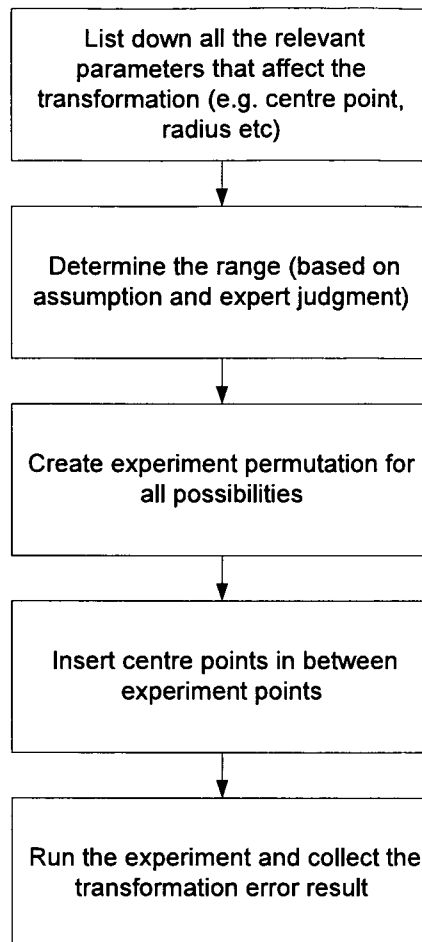


Figure 3

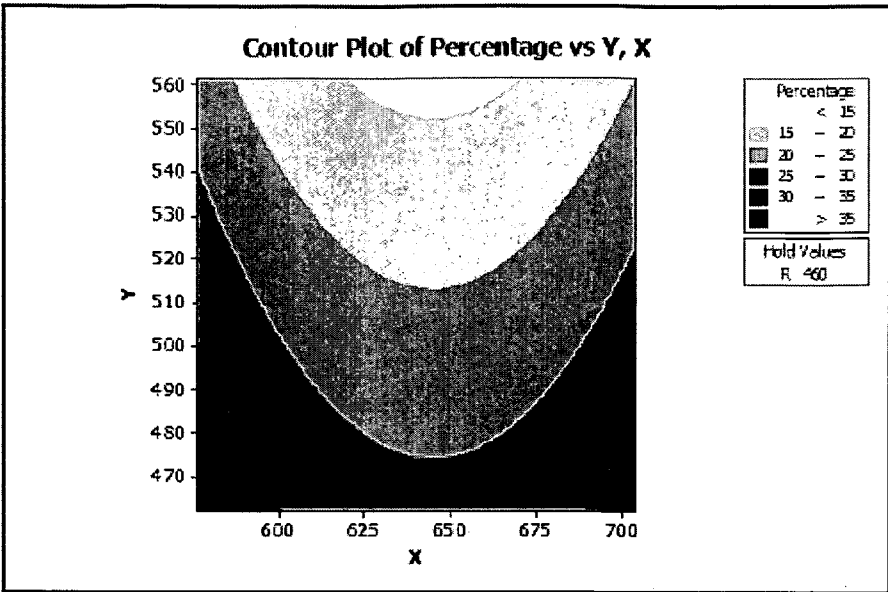


Figure 4

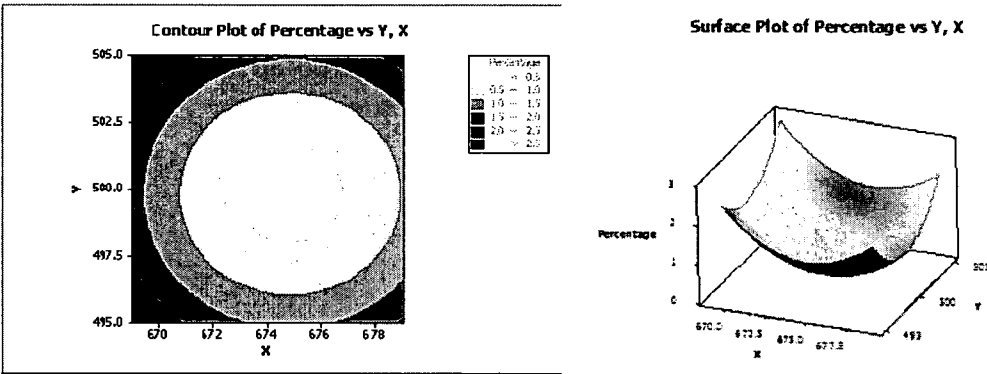


Figure 5

A. CLASSIFICATION OF SUBJECT MATTER***H04N 17/00(2006.01)i, H01L 27/14(2006.01)i***

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)

H04N 17/00; G03B 43/00; H04N 5/225; G01C 17/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: camera, optimum, transformation

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 7321838 B2 (JOHN C. KRUMM) 22 January 2008 See abstract; columns 7-9 ;, figs. 4, 5; claim 1	1-7
A	KR 10-2009-0096746 A (ACUTELOGIC CORPORATION) 14 September 2009 See abstract; paragraphs 65-72, 119-121; figs. 3, 4; claim 1	1-7
A	KR 10-2000-0020636 A (LG ELECTRONICS INC.) 15 April 2000 See abstract; pages 2-3; fig. 2; claim 1	1-7



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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Korean Intellectual Property Office
Government Complex-Daejeon, 189 Cheongsu-ro,
Seo-gu, Daejeon 302-701, Republic of Korea

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Authorized officer

KIM, Hee Ju

Telephone No. 82-42-481-8494



INTERNATIONAL SEARCH REPORT

Information on patent family members

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