METHOD AND SYSTEM FOR MEASURING VOLUME OF STOCKPILE

BACKGROUND OF THE INVENTION

Technical Field

[0001] The present invention relates generally to a measuring method and a measuring system; and more particularly to a method for measuring a volume of a stockpile and a system for measuring a volume of a stockpile.

Description of Related Art

[0002] Traditionally, measuring a volume of a salt stockpile requires a surveyor to be physically present at a site to conduct on-site measurements, and measurement data are manually organized and calculated. Currently, the measurement of stockpile volume mainly relies on the use of a total station or a terrestrial LiDAR scanner.

[0003] The total station is a high-precision measuring instrument capable of simultaneously measuring horizontal angles, vertical angles, and distances. During the measurement process, the surveyor needs to perform multiple on-site measurements to ensure the accuracy of the measurement data. Although the method could yield precise results, it is complex and time-consuming, leading to inefficiencies in the measurement process. The terrestrial LiDAR scanner generates a plurality of high-precision 3D point clouds through laser scanning, which could be used for accurate volume calculations of the salt stockpile. However, the terrestrial LiDAR scanner is expensive and requires regular maintenance, while data processing and volume measurements still need to be performed manually, consuming significant time and labor, making it difficult to execute frequently. As a result, real-time monitoring of inventory changes in the salt stockpile is not feasible.

[0004] Therefore, finding ways to improve the execution efficiency of a method for measuring a volume of a stockpile, as well as reduce labor costs to achieve real-time

monitoring of inventory changes in the stockpile, is an urgent problem that needs to be solved.

BRIEF SUMMARY OF THE INVENTION

[0005] In view of the above, the primary objective of the present invention is to provide a method for measuring a volume of a stockpile and a system for measuring a volume of a stockpile, which could improve the efficiency of stockpile volume measurement.

[0006] The present invention provides a method for measuring a volume of a stockpile, wherein the stockpile is located in a stockpile yard. The stockpile yard includes a plurality of control points. The method for measuring the volume of the stockpile includes steps of:

[0007] A. providing a plurality of images surrounding the stockpile yard and transmitting the images to a storage device, wherein each of the images includes a portion of the stockpile;

[0008] B. reading the images from the storage device by a processing device;

[0009] C. calculating, by the processing device, an overlap rate between two adjacent images, and selecting, by the processing device, a plurality of filtered images based on the overlap rates, wherein if the overlap rate of any image is less than a predetermined value, that image is selected as the filtered image;

[0010] D. performing image enhancement on the filtered images to create a plurality of enhanced images by the processing device;

[0011] E. detecting the control points in the enhanced images and obtaining a plurality of image coordinates of each of the control points by the processing device;

[0012] F. calculating, by the processing device, a plurality of 3D point clouds of the stockpile yard and a surface of the stockpile based on a plurality of absolute 3D

coordinates and the image coordinates of the control points, and generating, by the processing device, a digital surface model;

[0013] G. subtracting a digital terrain model from the digital surface model, by the processing device, to obtain a digital stockpile model, wherein the digital stockpile model is a 3D model of the stockpile; and

[0014] H. calculating, by the processing device, a volume of the digital stockpile model.

[0015] The present invention also provides a system for measuring a volume of a stockpile, wherein the stockpile is located in a stockpile yard. The stockpile yard includes a plurality of control points. The system for measuring the volume of the stockpile includes at least one imaging device, a storage device and a processing device. The at least one imaging device is used to capture a plurality of images of the stockpile yard, wherein each of the images includes a portion of the stockpile. The storage device is electrically connected to the at least one imaging device, wherein the storage device is used to the store the images. The processing device is electrically connected to the storage device, wherein the processing device reads the images from the storage device; the processing device calculates an overlap rate between two adjacent images and selects a plurality of filtered images based on the overlap rates; if the overlap rate of any image is less than a predetermined value, that image is selected as the filtered image; the processing device performs image enhancement on the filtered images to create a plurality of enhanced images; the processing device detects the control points in the enhanced images and obtains a plurality of image coordinates of each of the control points; the processing device calculates a plurality of 3D point clouds of the stockpile yard and a surface of the stockpile based on a plurality of absolute 3D coordinates and the image coordinates of the control points; the processing device generates a digital surface model; the processing device subtracts a digital terrain model from the digital surface model to obtain a digital

stockpile model, wherein the digital stockpile model is a 3D model of the stockpile; the processing device calculates a volume of the digital stockpile model.

[0016] Through filtering out the images with excessively high overlap rates, preventing issues that could affect subsequent image matching efficiency or lead to the failure of bundle aerial triangulation, thereby improving volume calculation efficiency. The method for measuring the volume of the stockpile also enhances the filtered images to increase image detail, which in turn improves the success rate of image matching and bundle aerial triangulation. Furthermore, the method could automatically acquire the image coordinates of each control point, replacing manual measurements to reduce human error and further enhance the execution efficiency of the method for measuring the volume of the stockpile, enabling real-time monitoring of inventory changes in the stockpile.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0017] The present invention would be best understood by referring to the following detailed description of some illustrative embodiments in conjunction with the accompanying drawings, in which

[0018] FIG. 1 is a schematic view of the method for measuring the volume of the stockpile, showing that the stockpile is located in the stockpile yard, according to an embodiment of the present invention;

[0019] FIG. 2 is a schematic view of the system for measuring the volume of the stockpile according to the embodiment of the present invention;

[0020] FIG. 3 is a flowchart of the method for measuring the volume of the stockpile according to the embodiment of the present invention;

[0021] FIG. 4 is a schematic view of the method for measuring the volume of the stockpile, showing the filtered image and the enhanced image, according to the embodiment of the present invention;

[0022] FIG. 5 is a schematic view of the method for measuring the volume of the

stockpile, showing the label sub-images, according to the embodiment of the present invention;

[0023] FIG. 6 is a schematic view of the method for measuring the volume of the stockpile, showing the use the corner of the marking line in each label sub-image to correspond to the image coordinates of each label template image, according to the embodiment of the present invention;

[0024] FIG. 7 is a schematic view of the method for measuring the volume of the stockpile, showing the digital surface model, the digital terrain model, and the digital stockpile model, according to the embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0025] A method for measuring a volume of a stockpile according to an embodiment of the present invention is illustrated in FIG. 1 and is used to measure the volume of the stockpile 20 located in a stockpile yard 10.

[0026] In the current embodiment, the stockpile yard 10 is a salt storage facility, and the stockpile 20 is a salt stockpile, but not limited thereto.

[0027] In the current embodiment, the stockpile yard 10 is a circular enclosed area with a radius of 60 meters, wherein a terrain of the stockpile yard 10 gradually rises from an outer perimeter toward a central point. The stockpile yard 10 includes a center column 18, a conveyor frame 14, a wall surface 16, and a plurality of control points 12.

[0028] Referring to FIG. 1, a bottom portion of the center column 18 is fixed at the central point of the stockpile yard 10, and a top portion of the center column 18 is connected to the conveyor frame 14. The conveyor frame 14 could rotate around the center column 18 and is adapted to transport the stockpile 20 to a stockpile area A of the stockpile yard 10. Additionally, the conveyor frame 14 is disposed above the stockpile 20. The wall surface 16 surrounds the stockpile yard 10. The control points 12 are fixed to the wall surface 16 in an evenly spaced arrangement. In the current embodiment, the number

of the control points 12 is eighteen. Each of the control points 12 has a label 122, and a marking line 124 is disposed below each of the labels 122.

[0029] In the current embodiment, the stockpile yard 10 includes a non-stockpile area B, which includes the center column 18, the conveyor frame 14, and the wall surface 16. Moreover, the stockpile area A is for storing the stockpile.

[0030] A system for measuring the volume of the stockpile 100 according to the current embodiment is illustrated in FIG. 2 and is used to implement the method for measuring the volume of the stockpile in the current embodiment. The system for measuring the volume of the stockpile 100 includes at least one imaging device 30, a storage device 40, and a processing device 50.

[0031] As shown in FIG. 1 and FIG. 2, the at least one imaging device 30 is electrically connected to the storage device 40. The at least one imaging device 30 is used to capture a plurality of images of the stockpile yard 10 and transmit the images to the storage device 40. In the current embodiment, the number of the imaging device 30 is two, wherein the imaging devices 30 are fixed to the conveyor frame 14 to capture the images of the stockpile yard 10 from a vertical angle. One of the imaging devices 30 is disposed closer to the center column 18 than the other imaging device 30, and the imaging devices 30 are digital industrial cameras.

[0032] In other embodiments, the number of the imaging device 30 could be one or more than two. In another embodiment, the imaging device 30 could be fixed to a drone to capture images of the stockpile yard 10.

[0033] As shown in FIG. 1, the storage device 40 is electrically connected to processing device 50. The storage device 40 is used to the store the images and transmit the images to the processing device 50.

[0034] The processing device 50 is used for overlap rate filtering, image enhancement, automatically identifying image coordinates, and constructing a 3D model

of the stockpile yard 10 based on the data from the images to measure the volume of the stockpile 20. The processing device 50 might be, for example, a personal computer, a workstation, or a server. The storage device 40 might be installed within the processing device 50.

[0035] The system for measuring the volume of the stockpile 100 is used to fully automate the execution of the method for measuring the volume of the stockpile according to the present invention. In other embodiments, the use of other measuring systems to implement the method for measuring the volume of the stockpile is not excluded. The method for measuring the volume of the stockpile would be described together with the system for measuring the volume of the stockpile 100.

[0036] In the current embodiment, the method for measuring the volume of the stockpile, as shown in FIG. 3, includes the following steps:

[0037] Step S11: providing the images surrounding the stockpile yard 10 and transmitting the images to the storage device 40.

[0038] In the current embodiment, when the conveyor frame 14 moves to a starting position and begins to rotate around the center column 18, the imaging devices 30 capture images of the stockpile yard 10 synchronously at a fixed shooting frequency, obtaining the images surrounding the stockpile yard 10 and transmitting the images to the storage device 40. Each of the images includes a portion of the stockpile 20. Each of the images could be transmitted to the storage device 40 for storage synchronously through the imaging devices 30, or the imaging devices 30 could temporarily store all the images first and then transmit the images to the storage device 40 for storage.

[0039] In other embodiments, the images surrounding the stockpile yard 10 could be captured by the drone equipped with the imaging device 30 flying around the stockpile yard 10.

[0040] Step S12: reading the images from the storage device 40 by the processing device 50.

[0041] In the current embodiment, the processing device 50 loads the images from the storage device 40.

[0042] Step S13: calculating, by the processing device 50, an overlap rate between two adjacent images, and selecting, by the processing device 50, a plurality of filtered images 60 based on the overlap rates.

[0043] First, the processing device 50 uses an image feature extraction technology to perform feature matching of the images. In the current embodiment, the processing device 50 utilizes the N-surf (Normalized Speed-Up Robust Feature) image feature extraction technology for feature matching. N-surf increases the number of candidate features through a single image scale and calculates the cumulative distribution function (CDF) of the feature threshold (FT) to obtain the desired number of features. This ensures that a consistent number of features are extracted across different scenes and between various bands of multispectral (MS) images.

[0044] When the processing device 50 performs feature matching on each of the images to obtain a plurality of image coordinates of a conjugate point, the processing device 50 then calculates the overlap rate between adjacent images. Specifically, each of the images has an image width in a short-axis direction. The processing device 50 utilizes the image coordinates of the conjugate points of the two adjacent images to calculate the average of the differences between the image coordinates of the two conjugate points and then takes the square root of the sum of the squares to obtain a coordinate distance (unit: pixels). The overlap rate between the two adjacent images is then calculated using the formula (1 - coordinate distance / image width) * 100%.

[0045] When the processing device 50 obtains the overlap rates of the images, the processing device 50 selects the filtered images 60 based on the overlap rates. Specifically,

if the overlap rate of any image is less than a predetermined value, that image is selected as the filtered image 60. In the current embodiment, the predetermined value is 95%. In other embodiments, the predetermined value is not limited to this, and a user could set the predetermined value according to their specific needs.

[0046] By filtering out the images with excessively high overlap rates through the processing device 50, the processing device 50 could avoid issues related to low image matching efficiency or the inability to perform bundle aerial triangulation when constructing the 3D model of the stockpile yard 10.

[0047] Step S14: performing image enhancement on the filtered images 60 to create a plurality of enhanced images 62 by the processing device 50.

[0048] As shown in FIG. 4, in the current embodiment, the processing device 50 performs image enhancement on the filtered images 60 using Contrast Limited Adaptive Histogram Equalization (CLAHE) to create the enhanced images 62. Specifically, Contrast Limited Adaptive Histogram Equalization works by dividing each of the filtered images 60 into a plurality of blocks and applying histogram equalization (HE) to each of the blocks individually. This approach enhances the contrast of the local areas in each of the filtered images 60 while simultaneously avoiding noise amplification and loss of details within each of the filtered images 60.

[0049] In the current embodiment, the stockpile 20 is exemplified by the salt stockpile. Due to the salt stockpile being white and having less distinct textures, performing image enhancement by the processing device 50 could effectively increase the image details, which is beneficial for the processing device 50 in subsequently constructing the 3D model of the stockpile yard 10, thereby improving the success rate of image matching and performing bundle aerial triangulation.

[0050] Step S15: detecting the control points 12 in the enhanced images 62 and obtaining a plurality of image coordinates of each of the control points 12 by the processing device 50.

[0051] In the current embodiment, the processing device 50 uses an end-to-end object detection algorithm (such as Ultralytics YOLOv8) to detect the control points 12 in the enhanced images 62. Specifically, as shown in FIG. 5, the processing device 50 identifies the label 122 of each of the control points 12 in the enhanced images 62 through the end-to-end object detection algorithm and extracts a portion of each enhanced image 62 that includes the label 122 and the marking line 124 as a label sub-image 64.

[0052] The processing device 50 obtains a plurality of label template images. Each of the label template images corresponds to a plurality of image coordinates and includes the label 122 and the marking line 124.

[0053] Next, the processing device 50 matches the label sub-images 64 with each of the label template images using the normalized cross-correlation (NCC) method and selects the label template image with the highest similarity index for each label sub-image 64. As shown in Fig. 6, the processing device 50 uses a corner 124a of the marking line 124 in each label sub-image 64 to correspond to the image coordinates of each label template image, thereby obtaining the image coordinates corresponding to each control point 12.

[0054] The image coordinates of each control point 12 are automatically obtained by the processing device 50, replacing the manual measurement of the image coordinates of each control point 12. This not only enhances the execution efficiency of the method for measuring the volume of the stockpile but also reduces human errors, ensuring that the positioning of each control point 12 is more accurate and consistent, which in turn aids in the efficient management and analysis of the volume of the stockpile 20.

[0055] Step S16: calculating, by the processing device 50, a plurality of 3D point clouds of the stockpile yard 10 and a surface of the stockpile 20 based on a plurality of absolute 3D coordinates and the image coordinates of the control points 12, and generating, by the processing device 50, a digital surface model 70.

[0056] In the current embodiment, the processing device 50 uses the software tool Agisoft Metashape, which could automatically generate a 3D model based on images, to perform step S16.

[0057] In the current embodiment, after the processing device 50 obtains the absolute 3D coordinates of the control points 12 and a plurality of interior orientation parameters of each imaging device 30, the processing device 50 performs bundle aerial triangulation using the absolute 3D coordinates and the image coordinates of the control points 12 to obtain a plurality of exterior orientation parameters of each enhanced image 62 and a plurality of tie points, while simultaneously optimizing the interior orientation parameters. The absolute 3D coordinates of the control points 12 are measured manually in advance.

[0058] Next, the processing device 50 filters out a plurality of unusable tie points from the tie points to obtain a plurality of filtered tie points. Specifically, the unusable tie points include a plurality of unreliable tie points, a plurality of weak geometric tie points, and a plurality of tie points with large reprojection errors. The unreliable tie points result from erroneous matches caused by blurriness in some of the enhanced images 62; the weak geometric tie points are located in areas where geometric features are not distinct or do not provide sufficient geometric information; and the tie points with large reprojection errors are those that have inconsistent positions across the enhanced images 62. This filtering process optimizes the results of the bundle aerial triangulation, enhancing the accuracy and reliability of the constructed model.

[0059] The processing device 50 obtains a plurality of dense 3D point clouds through dense image matching based on the exterior orientation parameters of each enhanced image 62 and the filtered tie points. The processing device 50 filters out the 3D points in the dense 3D point clouds that have confidence intervals below a threshold, where the threshold for the confidence interval could be set according to the user's requirements. The processing device 50 fills the gaps in the dense 3D point clouds and classifies the 3D points of the stockpile area A and the surface of the stockpile 20, as well as the 3D points of the non-stockpile area B. As shown in FIG. 7, the processing device 50 interpolates to generate the digital surface model 70 based on the 3D points of the stockpile area A and the surface of the stockpile 20. The dimensions of the digital surface model 70 correspond to real-world dimensions.

[0060] Step S17: subtracting a digital terrain model 72 from the digital surface model 70, by the processing device 50, to obtain a digital stockpile model 74.

[0061] As shown in FIG. 7, after the processing device 50 obtains the digital terrain model 72 which is pre-constructed, the digital surface model 70 is subtracted by the digital terrain model 72 to obtain the digital stockpile model 74. The digital terrain model 72 represents a 3D model of the stockpile area A without the stockpile 20. The dimensions of the digital terrain model 72 correspond to real-world measurements. The digital surface model 70 is a 3D model of both the stockpile area A and the surface of the stockpile 20. The digital stockpile model 74 is a 3D model of the stockpile 20.

[0062] Step S18: calculating, by the processing device 50, a volume of the digital stockpile model 74.

[0063] The processing device 50, after obtaining the digital stockpile model 74, could calculate the volume of the digital stockpile model 74 since the dimensions of the digital stockpile model 74 correspond to real-world measurements. This allows for the determination of the volume of the stockpile 20.

[0064] In summary, the method for measuring the volume of the stockpile automatically filters out images with excessively high overlap rate, preventing issues that could affect subsequent image matching efficiency or lead to the failure of bundle aerial triangulation, thereby improving volume calculation efficiency. The method for measuring the volume of the stockpile also enhances the filtered images 60 to increase image detail, which in turn improves the success rate of image matching and bundle aerial triangulation. Furthermore, the method could automatically acquire the image coordinates of each control point 12, replacing manual measurements to reduce human error and further enhance the execution efficiency of the method for measuring the volume of the stockpile, enabling real-time monitoring of inventory changes in the stockpile. Additionally, the processing device 50 could calculate the weight of the stockpile based on its volume and density.

[0065] It must be pointed out that the embodiments described above are only some preferred embodiments of the present invention. All equivalent structures which employ the concepts disclosed in this specification and the appended claims should fall within the scope of the present invention.

WHAT IS CLAIMED IS:

1. A method for measuring a volume of a stockpile, wherein the stockpile is located in a stockpile yard, and the stockpile yard comprises a plurality of control points; the method for measuring the volume of the stockpile comprises steps of:

A. providing a plurality of images surrounding the stockpile yard and transmitting the images to a storage device, wherein each of the images comprises a portion of the stockpile;

B. reading the images from the storage device by a processing device;

C. calculating, by the processing device, an overlap rate between two adjacent images, and selecting, by the processing device, a plurality of filtered images based on the overlap rates, wherein if the overlap rate of any image is less than a predetermined value, that image is selected as the filtered image;

D. performing image enhancement on the filtered images to create a plurality of enhanced images by the processing device;

E. detecting the control points in the enhanced images and obtaining a plurality of image coordinates of each of the control points by the processing device;

F. calculating, by the processing device, a plurality of 3D point clouds of the stockpile yard and a surface of the stockpile based on a plurality of absolute 3D coordinates and the image coordinates of the control points, and generating, by the processing device, a digital surface model;

G. subtracting a digital terrain model from the digital surface model, by the processing device, to obtain a digital stockpile model, wherein the digital stockpile model is a 3D model of the stockpile; and

H. calculating, by the processing device, a volume of the digital stockpile model.

2. The method for measuring the volume of the stockpile as claimed in claim 1, wherein the stockpile yard comprises a conveyor frame disposed above the stockpile; the

conveyor frame could rotate around a center of the stockpile yard; at least one imaging device is fixed to the conveyor frame to capture the images of the stockpile yard; the control points of the stockpile yard are fixed to a wall surface of the stockpile yard; in step A, during the rotation of the conveyor frame, the at least one imaging device captures the images of the stockpile yard to obtain the images surrounding the stockpile yard.

3. The method for measuring the volume of the stockpile as claimed in claim 1, wherein each of the images has an image width in a short-axis direction; in step C, the processing device uses an image feature extraction technology to perform feature matching of the images and obtains a plurality of image coordinates of a conjugate point of each of the images; a coordinate distance between two adjacent images is calculated using the image coordinates of the conjugate points of the two adjacent images; the overlap rate between the two adjacent images is then calculated using the formula (1 - coordinate distance/image width) * 100%.

4. The method for measuring the volume of the stockpile as claimed in claim 1 or 3, wherein the predetermined value is 95%.

5. The method for measuring the volume of the stockpile as claimed in claim 1, wherein in step D, the processing device performs image enhancement on each of the filtered images using Contrast Limited Adaptive Histogram Equalization (CLAHE).

6. The method for measuring the volume of the stockpile as claimed in claim 1 or 5, wherein each of the control points has a label, and a marking line is disposed below each of the labels; step E comprises the following steps:

identifying, by the processing device, the label of each of the control points in the enhanced images, and extracting, by the processing device, a portion of each enhanced image that comprises the label and the marking lines as a label sub-image;

obtaining a plurality of label template images by the processing device, wherein each of the label template images corresponds to a plurality of image coordinates;

matching, by the processing device, the label sub-images with each of the label template images using the normalized cross-correlation (NCC) method, and selecting, by the processing device, the label template image with the highest similarity index for each label sub-image;

using, by the processing device, a corner of the marking line in each label sub-image to correspond to the image coordinates of each label template image, thereby obtaining the image coordinates corresponding to each control point.

7. The method for measuring the volume of the stockpile as claimed in claim 1, wherein the stockpile yard comprises a stockpile area and a non-stockpile area; the stockpile area is for storing the stockpile; step F comprises the following steps:

performing, by the processing device, bundle aerial triangulation on the enhanced images to obtain a plurality of exterior orientation parameters of each enhanced image and a plurality of tie points;

filtering, by the processing device, a plurality of unusable tie points from the tie points to obtain a plurality of filtered tie points;

obtaining, by the processing device, a plurality of dense 3D point clouds through dense image matching based on the exterior orientation parameters of each enhanced image and the filtered tie points;

filtering, by the processing device, the 3D points in the dense 3D point clouds that have confidence intervals below a threshold;

classifying, by the processing device, the 3D points of the stockpile area and the surface of the stockpile, as well as the 3D points of the non-stockpile area;

generating, by the processing device, the digital surface model based on the 3D points of the stockpile area and the surface of the stockpile.

8. A system for measuring a volume of a stockpile, wherein the stockpile is located in a stockpile yard, and the stockpile yard comprises a plurality of control points; the system

for measuring the volume of the stockpile comprises:

at least one imaging device used to capture a plurality of images of the stockpile yard, wherein each of the images comprises a portion of the stockpile;

a storage device electrically connected to the at least one imaging device, wherein the storage device is used to the store the images; and

a processing device electrically connected to the storage device, wherein the processing device reads the images from the storage device; the processing device calculates an overlap rate between two adjacent images and selects a plurality of filtered images based on the overlap rates; if the overlap rate of any image is less than a predetermined value, that image is selected as the filtered image; the processing device performs image enhancement on the filtered images to create a plurality of enhanced images; the processing device detects the control points in the enhanced images and obtains a plurality of image coordinates of each of the control points; the processing device calculates a plurality of 3D point clouds of the stockpile yard and a surface of the stockpile based on a plurality of absolute 3D coordinates and the image coordinates of the control points; the processing device generates a digital surface model; the processing device subtracts a digital terrain model from the digital surface model to obtain a digital stockpile model, wherein the digital stockpile model is a 3D model of the stockpile; the processing device calculates a volume of the digital stockpile model.

9. The system for measuring the volume of the stockpile as claimed in claim 8, wherein each of the images has an image width in a short-axis direction; the processing device uses an image feature extraction technology to perform feature matching of the images and obtains a plurality of image coordinates of a conjugate point of each of the images; a coordinate distance between two adjacent images is calculated using the image coordinates of the conjugate points of the two adjacent images; the overlap rate between the two adjacent images is then calculated using the formula (1 - coordinate

distance/image width) * 100%.

10. The system for measuring the volume of the stockpile as claimed in claim 8, wherein each of the control points has a label, and a marking line is disposed below each of the labels; the processing device identifies the label of each of the control points in the enhanced images and extracts a portion of each enhanced image that comprises the label and the marking lines as a label sub-image; the processing device obtains a plurality of label template images, wherein each of the label template images corresponds to a plurality of image coordinates; the processing device matches the label sub-images with each of the label template images using the normalized cross-correlation (NCC) method and selects the label template image with the highest similarity index for each label sub-image; the processing device uses a corner of the marking line in each label sub-image to correspond to the image coordinates of each label template image, thereby obtaining the image coordinates corresponding to each control point.